Mineral Resources of the Newberry Mountains and Rodman Mountains Wilderness Study Areas, San Bernardino County, California

U.S. GEOLOGICAL SURVEY BULLETIN 1712–A

Chapter A

Mineral Resources of the Newberry Mountains and Rodman Mountains Wilderness Study Areas, San Bernardino County, California

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U.S. GEOLOGICAL SURVEY BULLETIN 1712

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
CENTRAL CALIFORNIA DESERT CONSERVATION AREA

DEPARTMENT OF THE INTERIOR
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STUDIES RELATED TO WILDERNESS

Bureau of Land Managment 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 be submitted to the President and the Congress. This report presents the results of a mineral survey of parts of the Newberry Mountains (CDCA-206) and Rodman Mountains (CDCA-207) Wilderness Study Areas, California Desert Conservation Area, San Bernardino County, California.

CONTENTS

FIGURES

TABLES

Mineral Resources of the Newberry Mountains and Rodman Mountains Wilderness Study Areas, San Bernardino County, California

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SUMMARY

Abstract

The Newberry Mountains (CDCA-206) and Rodman Mountains (CDCA-207) Wilderness Study Areas occupy adjacent mountain ranges in the central Mojave Desert, 10 to 30 mi southeast of Barstow, Calif. The parts of the two study areas on which mineral surveys were requested encompass approximately 27,964 acres and 16,900 acres, respectively. Fieldwork conducted between 1983 and 1985 included geologic, geochemical, and geophysical studies by the U.S. Geological Survey and a survey of mines, prospects, and mineralized areas by the U.S. Bureau of Mines. There are no currently or formerly productive mineral deposits inside either study area. However, despite the lack of identified mineral resources, both study areas have localized potential for undiscovered resources, as discussed below.

The Newberry Mountains Wilderness Study Area contains two areas with mineral resource potential. (See appendix 1 for definitions of levels of mineral resource potential.) There is moderate potential for undiscovered epithermal gold and silver deposits in a zone crossing the west margin of the study area, and there is moderate potential for undiscovered epithermal silver deposits at the east end of the study area.

The Rodman Mountains Wilderness Study Area contains three areas with mineral resource potential. There is moderate potential for undiscovered small-scale vein deposits of gold, silver, and copper in two areas in the southwestern and north-central parts of the study area, and there is low potential for undiscovered placer gold in a small area near the northeast corner of the study area.

In this report, any references to the "wilderness study area" or the "study area" refer only to that part of the wilderness study area designated by the U.S. Bureau of Land Management as suitable for mineral surveys.

Character and Setting

The Newberry Mountains and Rodman Mountains Wilderness Study Areas lie adjacent to one another in the Mojave Desert of southeastern California (fig. 1). Both study areas are rugged and dry, consisting of sparsely vegetated ridges and steep-walled canyons occupied by sandy washes. The canyons open onto large alluvial fans along the northern margins of the study areas. The 1-mi gap between the study areas is occupied by the large northeast-trending canyon of Kane Wash.

Both study areas are underlain by Mesozoic (240 to 63 million years before present, or Ma; see Geologic Time Chart, last page of this report) plutonic rocks, by a diverse assemblage of earliest Miocene (approximately 24 to 20 Ma) intrusive, extrusive, and sedimentary rocks, and by Quaternary alluvium. The Newberry Mountains Wilderness Study Area is underlain predominantly by Miocene volcanic and sedimentary strata, which surround several hills of Mesozoic plutonic rocks. The plutonic rocks locally contain small pendants of Mesozoic metavolcanic rocks. The plutonic rocks and the Miocene strata are intruded by volcanic dikes of rhyolitic to intermediate composition, located mostly in the eastern part of the Newberry Mountains Wilderness Study Area.

The belt of Miocene strata and associated intrusive rocks continues east of Kane Wash where it underlies the northern and northeastern parts of the Rodman Mountains Wilderness Study Area. The southern two-thirds of the study area is underlain primarily by Mesozoic plutonic rocks. Miocene conglomerate and Pleistocene (approximately 0.6 Ma) basalt depositionally overlie the plutonic rocks in the central and northwestern parts of the study area.

The Miocene rocks in both study areas were strongly faulted and tilted moderately toward the southwest during intense regional northeast extension that was contemporaneous with early Miocene volcanism and sedimentation. Granitic rocks exposed along the north flank of the Newberry Mountains were

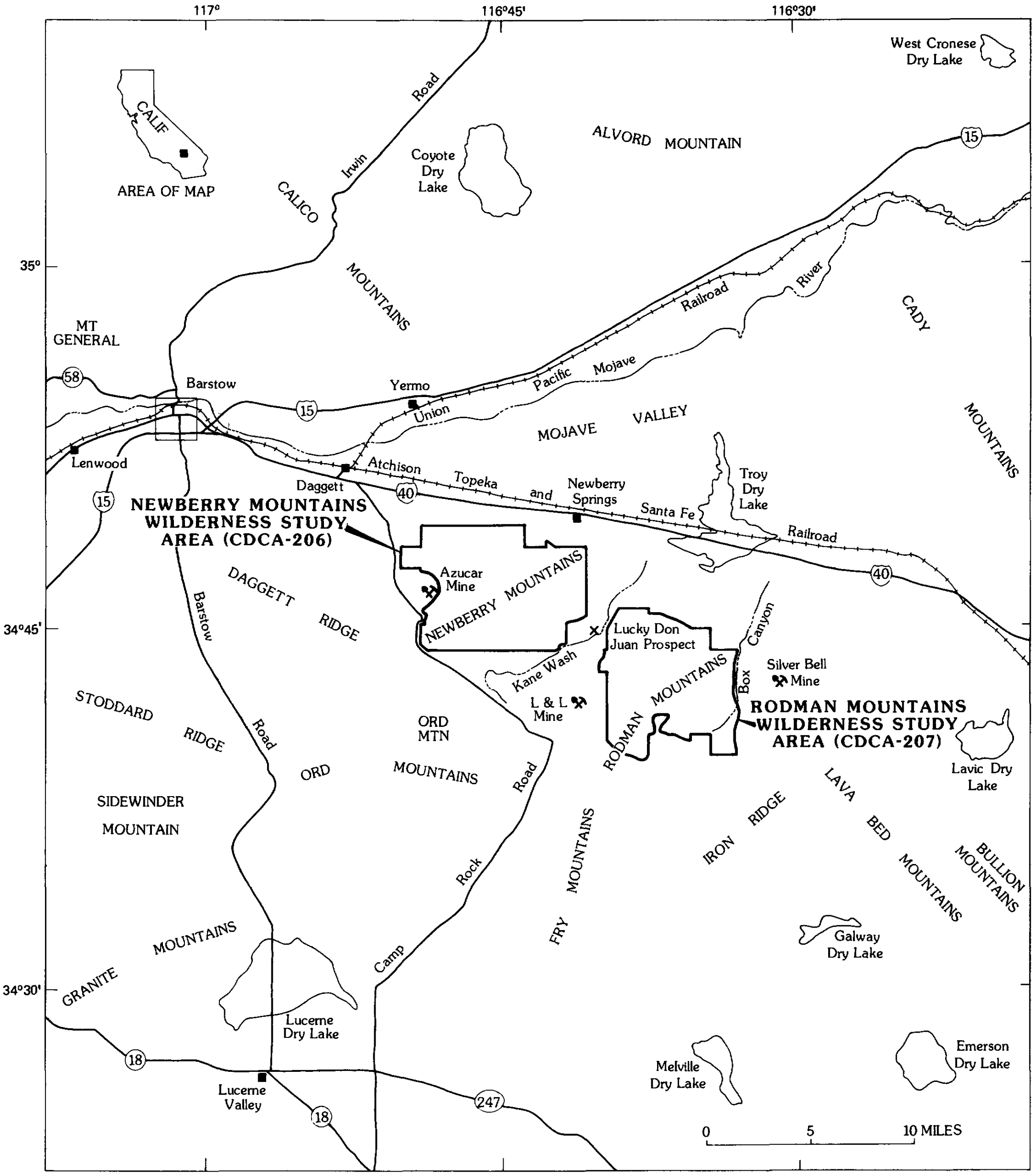


Figure 1. Index map showing location of the Newberry Mountains and Rodman Mountains Wilderness Study Areas.

strongly crushed and sheared during this extensional episode. Subsequent deformation of the region after early Miocene time has resulted from right-lateral movements along the Camp Rock and Calico faults (fig. 2).

Mining and prospecting within the central Mojave Desert region have occurred intermittently since the 1860's. There is no record of mineral production from either the Newberry Mountains or Rodman Mountains Wilderness Study Areas, but numerous prospects within and near these areas have revealed occurrences of gold, silver, copper, iron, barium, and manganese. All of these commodities have been mined in nearby ranges that are geologically similar to the Newberry and Rodman Mountains. In particular, silver has been produced in the Calico Mountains approximately 10 to 15 mi northwest of the Newberry Mountains; gold, silver, and copper have been mined in the Ord and Fry Mountains southwest of the Newberry and Rodman Mountains; and iron ore has been mined at Iron Ridge and on adjacent hills southeast of the Rodman Mountains (fig. 1). Nonmetallic materials, including clays, gravel, volcanic cinders, and boron- and strontium-bearing minerals, also have been produced from the surrounding region.

Mineral Resources and Potential for Undiscovered Resources

There are no identified mineral resources within either the Newberry Mountains or Rodman Mountains Wilderness Study Areas. However, on the basis of geologic and geochemical evidence and the distribution of known mineral occurrences, there is moderate potential for undiscovered gold and silver resources in the Newberry Mountains Wilderness Study Area; and there is moderate potential for undiscovered lode copper, gold, and silver resources and low potential for undiscovered placer gold resources in the Rodman Mountains Wilderness Study Area (fig. 2).

Newberry Mountains Wilderness Study Area

An east-trending zone crossing the west margin of the Newberry Mountains Wilderness Study Area (zone A on fig. 2) has a moderate potential for undiscovered gold and silver resources. This zone contains intersecting east- and north-trending faults that cut Miocene strata and locally juxtapose them against Mesozoic plutonic rocks. The combined presence of altered rocks, veins, geochemical anomalies for gold and silver, and a mine with a history of minor gold production (Azucar mine, 0.7 mi west of the study area) supports a moderate potential for undiscovered mineral resources; the zone also coincides with a linear aeromagnetic anomaly.

A broad zone of altered rocks that straddles the east margin of the study area has a moderate potential for undiscovered silver resources (zone B on fig. 2). This area consists mostly of Miocene extrusive and intrusive rocks of rhyolitic to andesitic composition that are locally enriched in secondary potassium feldspar. The combined presence of abundant Tertiary intrusions, potassium-feldspar alteration, and barium and silver geochemical anomalies supports a moderate potential for undiscovered mineral resources. In terms of geologic setting, rock alteration, and geochemical anomalies, this area is similar to mineralized areas of the Calico Mountains to the northwest, where silver is found in barite-rich veins associated with Miocene intrusive rocks and potassium-feldspar alteration.

Rodman Mountains Wilderness Study Area

Moderate potential for undiscovered gold, silver, and copper resources is ascribed to a zone at the southwest corner of the Rodman Mountains Wilderness Study Area (zone C on fig. 2). An examination of several prospects in this zone indicates potentially significant occurrences of copper, gold, and silver within veins and shear zones cutting plutonic rocks. Moderate potential for undiscovered gold, silver, and copper resources is also assigned to a second area in the north-central part of the study area (zone D on fig. 2) where anomalous geochemical abundances of copper and silver in a quartz vein and stream-sediment concentrates suggest that significant mineral concentrations might be present. Low potential for undiscovered placer gold resources is assigned to a small area near the northeast corner of the study area (zone E on fig. 2), where terrace gravels locally contain an anomalous amount of gold.

INTRODUCTION

Location and Physiography

The Newberry Mountains (CDCA-206) and Rodman Mountains (CDCA-207) Wilderness Study Areas occupy neighboring mountain ranges in the central Mojave Desert region 10 to 30 mi southeast of Barstow, Calif. (fig. 1). The study areas lie 1 to 5 mi south of Interstate Highway 40 and the Atchison, Topeka, and Santa Fe Railroad, and are directly east of a well-maintained unpaved county route, Camp Rock Road. Both study areas are located in dry, sparsely vegetated mountainous terrane.

The mineral survey of the Newberry Mountains Wilderness Study Area encompassed 27,964 acres of very rugged terrain with a total relief of about 3,000 ft. The sinuous crest of the Newberry Mountains, with summit elevations ranging from 3,300 to 5,100 ft, passes northeastward through the center of the study area. Several deep canyons are incised into the northern flank and eastern end of the range. These canyons emerge onto alluvial fans near the margins of the study area. The relatively gently sloping south flank of the Newberry Mountains contains several smaller canyons that are tributaries of Kane Wash, a northeast-flowing ephemeral stream that separates the Newberry Mountains from the Rodman Mountains to the southeast.

The Rodman Mountains Wilderness Study Area contains about 16,900 acres of moderately rugged terrane on the northern flank of the Rodman Mountains. Relief is slightly less than in the Newberry Mountains, totalling about 2,600 ft. Elevations increase southward from approximately 2,400 ft at the north margin of the study area to 5,000 ft near the south margin. Steep slopes and badlands topography

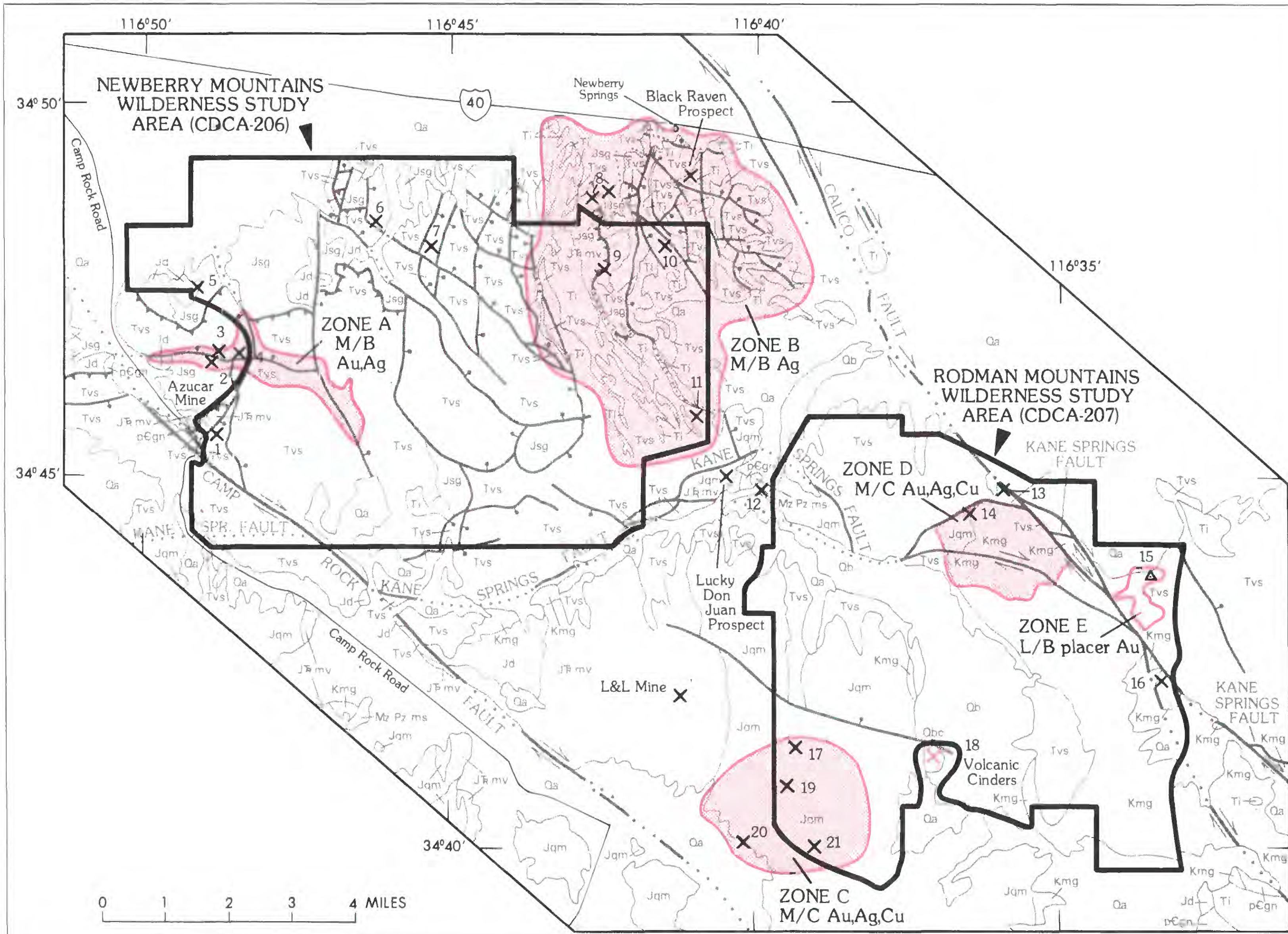


Figure 2. Map showing geology and mineral resource potential of the Newberry Mountains and Rodman Mountains Wilderness Study Areas.

EXPLANATION

Area with moderate mineral resource potential

Area with low mineral resource potential but with some indication of resource-forming processes

See Appendix 1 for definition of levels of mineral resource potential and certainty of assessment

×18 Mine with identified resources of volcanic cinders

Commodities

Ag	Silver
Au	Gold
Cu	Copper
	Volcanic cinders

Geologic map units

Qa	Alluvium (Holocene and Pleistocene)
Qb	Basalt (Pleistocene)
Qbc	Basalt cinders (Pleistocene)
Ti	Fine-grained intrusive rocks (Miocene)
Tvs	Volcanic and sedimentary rocks (Miocene)
Kmg	Monzogranite (Cretaceous)
Jsg	Syenogranite (Jurassic?)
Jqm	Quartz monzonite (Jurassic)
Jd	Diorite (Jurassic)
JTRmv	Metavolcanic rocks (Jurassic or Triassic)
MzPzms	Metasedimentary rocks (Mesozoic or Paleozoic)
p€gn	Gneiss (Precambrian)

Contact

Fault--Dotted where concealed; arrows indicate sense of lateral slip; bar and ball on downthrown side

Newberry Mountains detachment fault (Dokka, 1980, 1986)--Dotted where concealed; sawteeth on upper plate

×3 Mine or prospect without identified resources--Numbers refer to tables 1 and 2

△15 Placer gold occurrence indicated by stream-sediment geochemistry--Number refers to table 2

Figure 2. Continued.

dominate the northern part of the study area, but relatively gentle slopes prevail in the southern half of the area. One large area of gentle slopes is underlain by Pleistocene basalt flows that erupted near the south edge of the study area and flowed northwest to Kane Wash.

Access within the Newberry Mountains and Rodman Mountains Wilderness Study Areas is largely limited to foot travel. The margins of the areas can be reached by several dirt roads and jeep trails that originate from Camp Rock Road and from a paved road adjacent to Interstate Highway 40 east of Newberry Springs. Chief among these are a gas pipeline service road following Kane Wash and other dirt roads along the south and east margins of the Rodman Mountains Wilderness Study Area. Unimproved jeep trails extend up several canyons in the western and eastern parts of the Newberry Mountains Wilderness Study Area.

Previous Studies

Gardner (1940) and Tucker and Sampson (1940) were the first to map and describe the geology and mineral resources of the region in detail. The mines and mineral deposits of the region later were described by Wright and others (1953). A series of unpublished reports prepared for the Southern Pacific Railroad presented additional geologic mapping and mineral-resource evaluations (Anctil, 1956; Dorsey, 1956a, 1956b; Kojan, 1956; Stejer and Olcott, 1956). The U.S. Geological Survey mapped the geology of several 15-minute quadrangles that include the Newberry and Rodman Mountains (Dibblee, 1964a, 1964b, 1970; Dibblee and Bassett, 1966). Hawkins (1976) mapped an area astride the Camp Rock fault that extends into the west end of the Newberry Mountains Wilderness Study Area. Nason and others (1979) described Miocene volcanic rocks in the Newberry Mountains. Dokka (1980, 1983, 1986), Dokka and Glazner (1982), and Dokka and Woodburne (1986) described the Cenozoic tectonic history of the region and presented geologic maps of the Newberry Mountains area. Sanner (1985) mapped Miocene volcanic and sedimentary rocks in the northeastern Rodman Mountains. Both wilderness study areas are included in regional National Uranium Resource Evaluation studies conducted for the U.S. Department of Energy (Leedom and Kiloh, 1978; High Life Helicopters, Inc., 1980). Vredenburgh (1980) summarized the geology and mineral resources of both study areas and surrounding areas in an unpublished U.S. Bureau of Land Management report.

Procedures and Sources of Data

Field and laboratory studies conducted between 1983 and 1985, as well as previous reports and public documents, provided data for the conclusions of this report. General format and terminology follow the guidelines of Goudarzi (1984).

The U.S. Bureau of Mines reviewed literature, mining-claim records, and production records, and inspected mines, prospects, claims, and mineralized areas in and near the study areas. Rock samples collected from prospects and mineralized areas and alluvium collected from selected drainages were analyzed for elements of possible economic significance. These data were used to determine past and present mining and mineral exploration activities and to characterize mineral occurrences within and immediately adjacent to the study areas (Sabine, 1985; Kuizon, 1985).

The U.S. Geological Survey compiled a 1:48,000-scale geologic map covering both study areas, largely on the basis of detailed (1:24,000-scale) mapping conducted during the present investigation (B.F. Cox, unpub. data, 1986). A generalized version of this geologic map is shown on figure 2. Geologic quadrangle maps (Dibblee, 1964a, b, 1970; Dibblee and Bassett, 1966) were used as general references during field work and compilation of the map. Previous mapping southwest of the Camp Rock fault (Weber, 1963; Hawkins, 1976; and Karish, 1983) and northeast of the Calico fault (Sanner, 1985) is incorporated in simplified form. Many of the major structural features on the map, particularly the Kane Springs fault and Newberry Mountains detachment fault, were previously identified by Dokka (1980, 1986). Altered rocks potentially related to hydrothermal alteration or mineralization were identified from field observations and by inspection of Landsat multispectral-scanner images (fig. 3). Veins, altered rocks, and heavy-mineral concentrate samples from active stream channels were analyzed so that chemical variations reflecting concentrations of ore minerals could be identified (fig 4; Detra and Kilburn, 1985; B.F. Cox, unpub. data, 1986). The geophysical survey of the study areas involved compilation and interpretation of gravity and aeromagnetic maps based on both previous and new field measurements (figs. 5 and 6). The geologic, geochemical, and geophysical data were evaluated along with the information obtained by the U.S. Bureau of Mines to assess the potential for undiscovered mineral resources in the two study areas.

Acknowledgments

E.A. Rodriguez and R.L. Morin of the U.S. Geological Survey assisted with the geological and geophysical field studies. Geochemical analyses of rock samples collected by the U.S. Geological Survey were performed by J.G. Crock, L. Bradley, P.H. Briggs, T.L. Fries, T.P. Frost, and B. Libby. Personnel of the U.S. Bureau of Land Management Barstow Resource Area Office provided much helpful information, aerial photographs, and logistical support; special thanks to Daryl Albiston, Chris Rush, Ken Schulte, and Tim Smith. Thanks also to Don and Ruth Mulligan for information about the Flying M Association property (table 2).

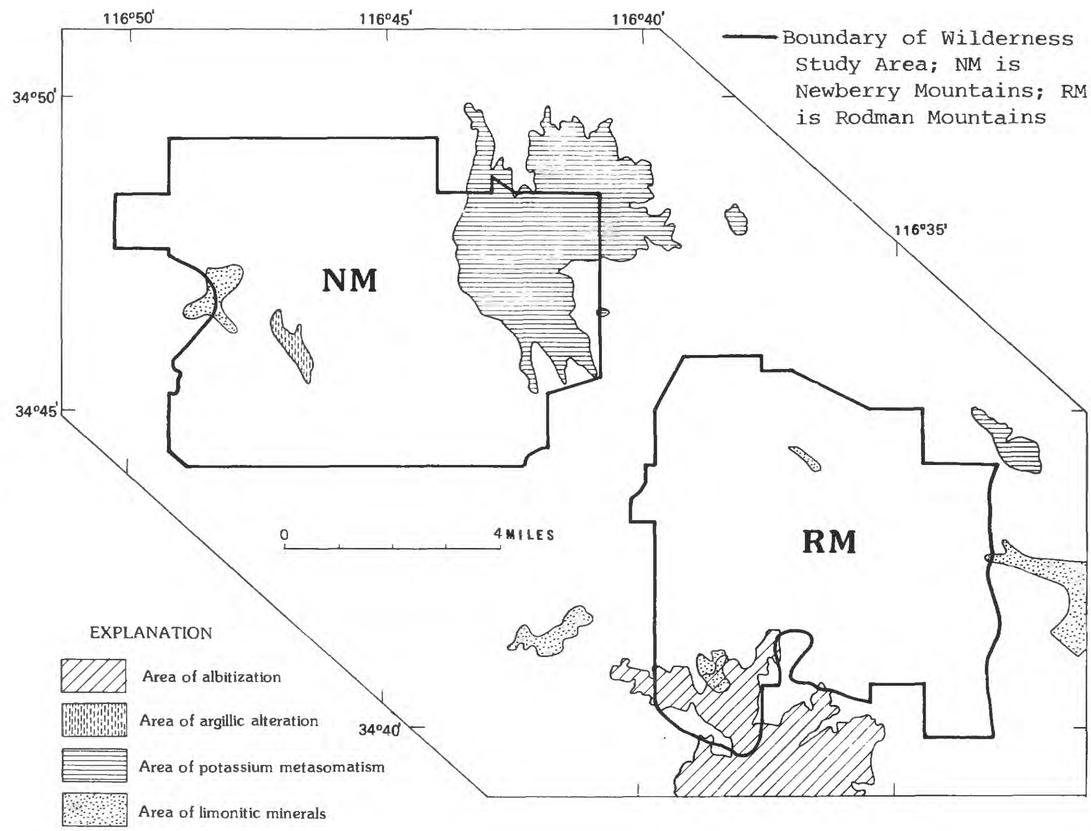


Figure 3. Map showing areas of altered rocks in the Newberry Mountains and Rodman Mountains Wilderness Study Areas.

APPRAISAL OF IDENTIFIED RESOURCES

by Charles Sabine and Lucia Kuizon,
U.S. Bureau of Mines

Field Work and Analytical Methods

In 1983, U.S. Bureau of Mines personnel examined and evaluated mines and prospects in and adjacent to the Newberry Mountains and Rodman Mountains Wilderness Study Areas (Sabine, 1985; Kuizon, 1985). Twenty mines and prospects were examined (tables 1 and 2) and 51 rock samples and 5 alluvial samples were collected. The alluvial samples were panned, concentrated on a Wilfley table[1], and checked microscopically for gold and other heavy minerals. Samples were analyzed for copper, gold, lead, silver, tungsten, and zinc by various quantitative methods, including fire assay, inductively coupled plasma, and x-ray fluorescence. At least one sample from each prospect was analyzed for 40 elements by semiquantitative emission-spectrographic analysis.

Regional History of Mining and Mineral Exploration

Mineral exploration began over 100 years ago in the central Mojave Desert region. No mines with recorded production are located within either of the study areas, but there has been significant mineral production in neighboring ranges where geologic conditions are similar in some respects to those in the study areas. Iron, silver, gold, and copper have been the most noteworthy metallic mineral products of the surrounding region.

Iron deposits at Iron Ridge and west of Galway Dry Lake (fig. 1) were mined during the 1940's and early 1950's (Wright and others, 1953; Dibblee, 1964b). The iron ore consists of metasomatic bodies of magnetite and hematite situated along contacts between granitic rocks and metamorphosed limestone and dolomite pendants. Reserves at Iron Ridge have been estimated at 1.8 million tons of ore containing 30-65 percent iron (Lamey, 1948). Two other iron prospects are located at the north end of the Fry Mountains (Dibblee, 1964b, site N) and at the north end of Ord Mountain (Weber, 1963). A contact-metasomatic tungsten occurrence also is present on the north flank of Ord Mountain (Weber, 1963).

In the Ord Mountains and Fry Mountains to the west and southwest of the Rodman Mountains, gold, silver, and copper minerals are associated with quartz veins and sheared rocks along north-trending faults and fissures that cut Mesozoic metavolcanic and plutonic rocks. Common gangue minerals are quartz, barite, epidote, fluorite, and hydrous iron oxides. Approximately 2,000 tons of ore mined primarily for copper and gold were produced from the Ord Mountain area between 1917 and 1942 (Weber, 1963). Veins and shear zones in the Fry Mountains produced ore valued mainly for its gold content (Dibblee, 1964b, sites F-K). Metavolcanic rocks similar to those that underlie much of the Ord Mountains are exposed between the two study areas in the southeastern Newberry Mountains and westernmost Rodman Mountains. These rocks have been explored at over 200 mining claims, including the Lucky Don Juan prospect and the former L & L mine, but no significant production has been recorded.

An historically important silver-mining district is located in the Calico Mountains region, 10 to 15 mi northwest of the Newberry Mountains (Weber, 1967). Silver occurs primarily in veins in Miocene extrusive and intrusive rocks; locally they form disseminated deposits in sedimentary rocks. Gangue minerals consist mostly of barite and jasper. Between 1892 and 1896, 15 to 20 million ounces of silver were extracted from mines in the Calico Mountains (Harthrong, 1983). Minor amounts of gold, copper, lead, and barite have been produced from the region.

The Calico Mountains lie within a southeast-trending belt of Tertiary precious-metal occurrences that extends from ranges near the Garlock fault southeast to the Bullion Mountains (Gardner, 1980). The study areas lie along this trend, and several mines and prospects in the northeastern Rodman Mountains have been developed in search of silver and other minerals (Dibblee, 1964b, site L; 1966, site D). These include the Silver Bell mine, about 2 mi east of the Rodman Mountains Wilderness Study Area (fig. 1). However, there has been no recorded production of gold, silver, and base metals from Tertiary rocks in either the Newberry and Rodman Mountains.

Sites Examined for this Study

Twenty mines and prospects in and adjacent to the study areas were examined for this study (fig. 2). Information concerning these properties is given in tables 1 and 2.

Newberry Mountains Wilderness Study Area

Eleven mines and prospects in and near the Newberry Mountains Wilderness Study Area were examined for this study (table 1); seven are located within the study area. Only two properties, the Azucar mine (fig. 2, no. 2) and the Northrup prospect (fig. 2, no. 10), had mineral occurrences.

The Azucar mine, located about 0.7 mi west of the study area, explores a gold-bearing quartz vein

[1]Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Bureau of Mines of the U.S. Geological Survey.

Table 1--Mines and prospects in and adjacent to the Newberry Mountains Wilderness Study Area (CDCA-206)
[Asterisk (*) indicates location outside study area]

Map no.	Name	Summary	Workings and production	Sample and resource data
1	Prospect	Gray andesite. No evidence of mineralization or alteration.	Twenty-ft-deep vertical shaft.	One sample; no significant mineral values.
2*	Azucar mine	Milky quartz vein, 1 ft thick, along fault in quartz monzonite and diorite. Vein strikes north, curving to northeast, dips 50° to 55° E.	Vein explored by two trenches and an inclined shaft said to be 135 ft deep with 120 ft of drifts (Wright and others, 1953), an adit that is caved 55 ft from the portal, two pits, and a trench. U.S. Bureau of Mines files indicate 6 oz of gold were recovered from 20 tons of ore in 1941.	Eleven samples; three samples from the vein contain 0.017-0.082 oz/ton gold and 0.046-0.151 oz/ton silver. Samples from other workings contain no significant mineral values.
3*	Prospect	Fanglomerate composed of andesite and other volcanic rock fragments. No evidence of mineralization.	Twenty-ft-long adit.	One sample; no significant mineral values.
4*	Prospect	Two vertical veins of brecciated calcite within andesite. One body 300 ft long, 10-40 ft thick, relief 80 ft; other body 150 ft long, 5-35 ft thick, relief 50 ft.	One cut at end of larger vein.	Four samples; no significant mineral values Occurrence is too small to be considered a source of lime or decorative stone.
5	Prospect	Dark gray diorite cut by thin dikes of iron-oxide-stained granite with segregations of white quartz. No evidence of mineralization.	Two trenches, 20 and 14 ft long.	Two samples; no significant mineral values.
6	Copenhagen West prospect	White to gray lapilli tuff. No evidence of mineralization.	One pit.	One sample; no significant mineral values.
7	Prospect	Colluvium composed of volcanic rock fragments. No evidence of mineralization.	One 20-ft-long adit, ruin of a dwelling. Adit may have been driven to develop a small spring.	One sample; no significant mineral values.
8*	Prospect	Iron-oxide-stained light-gray felsite. No evidence of mineralization.	Two cuts, 55 and 15 ft long. Several hundred tons removed for road fill during the 1950's (Dibblee and Bassett, 1966).	Three samples; no significant mineral values.
9	Prospect	Contact, iron-oxide-stained light-gray to pale-reddish-purple felsite on west and dark brown metamorphosed volcanic breccia on east. No evidence of mineralization.	Two small pits.	One sample; no significant mineral values.
10	Northrup prospect	Northwest-trending vein of psilomelane, pyrolusite, and calcite, 1 in. to 1 ft thick and 6 ft long, in volcanic breccia. Outcrops are obscured by colluvium. Locality is adjacent to a northwest-trending fault.	One bulldozer scraping, 45 by 20 ft.	One sample from the vein contained 49 percent MnO, 2.4 percent Fe_2O_3, 3.0 percent SiO_2, 1.3 percent Al_2O_3, and 0.56 percent K_2O. A spectrographic analysis indicates more than 10 percent barium. The occurrence is too small to be a manganese resource.
11	Prospect	White lapilli tuff. No evidence of mineralization.	One pit.	One sample; no significant mineral values.

Table 2--Mines, prospects, and mineralized sites in and adjacent to the Rodman Mountains Wilderness Study Area (CDCA-207)
[Asterisk (*) indicates location outside study area; underlining indicates property containing resources or possible resources]

Map no.	Name	Summary	Workings and production	Sample and resource data
12*	Kane Wash prospect	Pendant of metasedimentary rocks including marble and tactite in quartz monzonite. Area has been sheared and intruded by dikes. No metallic minerals were observed. Similar geology does not occur within the study area.	One 22-ft-long adit, one 25-ft-deep inclined shaft, two pits, one open cut, and numerous trenches.	Twelve samples of marble, tacite, gneiss, and dike rock were collected. One sample contains 0.01 oz/ton gold; three samples contain 0.2-0.3 oz/ton silver. Four samples of tactite contain 0.03 percent WO_3. Samples taken by Dorsey (1956b) contained minor gold, silver, and tungsten.
13	Fort Cady Road No. 1 prospect	Shear zone in andesite breccia containing calcite, chalcedony, copper minerals, and stilbite, a zeolite mineral. The shear zone is 5 ft wide, strikes N. 35° E., and dips 73° NW. The andesite breccia zone is over 500 ft wide and 1,500 ft long. It is truncated to the south and east by the Calico fault.	One 12-ft-long adit.	One chip sample has no significant mineral values.
14	Fort Cady Road No. 2 prospect	Quartz vein in shear zone in granitic rock strikes N. 10° W. and dips 50° NE.; ranges from 0.2 to 0.5 ft thick, and is exposed for 25 ft.	One 23-ft-long adit, two open cuts.	One chip and one select sample of the quartz vein contain trace and 0.3 oz/ton silver and 0.011 percent and 0.60 percent copper. Two chip samples of altered granitic rock in shear zone have no significant mineral values. A sample taken by Dorsey (1956b) contained trace gold and 0.1 oz/ton silver.
15	Alluvial sample site	Stream terrace deposit overlying basalt and andesite. Gravel deposit ranges to 4 ft thick and contains about 80 percent granitic clasts.	None.	One reconnaissance pan sample of alluvium contains 0.0165 oz/yd^3 gold. Total alluvium volume probably is about 300,000 yd^3. Exploration may reveal gold resources.
16	Box Canyon prospect	Monzogranite near Calico Fault. Prospect was noted by Kojan (1956), but not found during the U.S. Bureau of Mines field examination. Area was sampled as part of a uranium survey (Leedom and Kiloh, 1978).	None.	One chip sample contained 1 ppm U_3O_8, and 12.7 ppm, 1.4 ppm, and 3.3 ppm of equivalent thorium, uranium and potassium (Leedom and Kiloh, 1978).
17	Maralin No. 5 prospect	Altered siliceous andesite dike 2.8 to 4.0 ft thick in granitic rock contains chrysocolla, limonite, quartz, chlorite, epidote, and magnetite. The dike is sheared along contact, strikes N. 5° W., dips 75° SW., and can be traced by float for about 1,000 ft.	Seven-ft-deep pit.	Two chip samples of the dike contain 0.5 oz/ton silver and 0.56 percent copper, and 0.024 percent copper.
18*	Red Top Flat mine	Cinder cone is composed of red and black scoria and basalt fragments, and is partially breached. The cone is 300 ft high and covers 80 acres.	A quarry on the south face have been mined since the 1950's. An unknown amount of volcanic cinder was produced. About 12,000 tons have been produced since 1982 by current operators; future production is estimated at 12,000 tons/year.	Estimated reserves are 12 million tons of volcanic cinder suitable for lightweight aggregate and soil conditioner.
19	Valley prospect	Quartz vein as thick as 0.9 ft strikes north and dips 70° W. along contact between granitic country rock and porphyritic dike. Vein contains limonite pseudomorphs and boxwork, chalcopyrite, chrysocolla, and manganese dendrites. It can be traced by float for 125 ft between two pits. The granite contains sericite veinlets, brecciated feldspar, and minor magnetite and apatite.	Two pits 6 ft and 4 ft deep.	Two select samples; one contains 0.3 oz/ton gold and 0.95 percent copper, the the other contains 0.04 oz/ton gold, 0.8 oz/ton silver, and 0.40 percent copper.
20*	Flying M Association claim group (formerly known as Camp Rock Mine)	Gold occurs in Quaternary alluvial fan deposits ranging from 2 to 33 ft thick above granitic bedrock (Latker, 1979). These deposits do not extend into the study area. Two shear zones occur in an adit. One shear zone composed of limonite, gouge, and altered granitic rock is 0.15 to 0.5 ft thick, 35 ft long, strikes N. 15°-30° E., and dips 70° SE. The other is composed of white clay gouge 0.4 to 0.9 ft thick, 50 ft long, strikes N. 80° E. and dips 58° NW.	Trenches, test pits, and one 295-ft-long adit in bedrock with 15-ft-deep winze and two small stopes 10 ft and 12 ft high.	One pan sample of alluvium on granitic bedrock contains 0.0026 oz/yd^3 gold and trace garnet. Two chip samples of shear zones in adit contain 1.96 oz/ton gold, 0.1 oz/ton silver, 0.1 percent copper; and 0.01 oz/ton gold, 1.3 oz/ton silver, and 0.1 percent copper. Owners reported 26.5 ft averaging 0.0203 oz/yd^3 gold in one drill hole. Additional exploration may reveal gold resources.
21	Moonlight prospect	Barite vein as thick as 1.0 ft strikes N. 45° E., dips 90° , and contains quartz with limonite, chrysocolla, and other copper minerals. Vein not observed beyond shaft. Altered quartz monzonite country rock shows albitization and minor sericitization and kaolinization. Hornblende and biotite have been altered to epidote and chlorite. Minor amounts of magnetite, apatite, and sphene were also found.	A vertical shaft 22 ft deep.	One select vein sample contains 0.04 oz/ton gold, 0.1 oz/ton silver, 0.74 percent copper, and 26.7 percent barium.

within granitic rocks. U.S. Bureau of Mines files indicate 6 oz of gold were recovered from 20 tons of ore in 1941. Sample data from surface exposures (table 1) and the lack of significant recorded production suggest that mineral resources of economic grade are not likely to exist at the Azucar mine. However, the property could not be fully evaluated because underground workings were inaccessible.

The Northrup prospect is the only property located within the study area that contains a mineral occurrence. A 6-in-wide vein of manganese-oxide minerals (psilomelane and pyrolusite) and calcite lies within volcanic breccia and trends northwest parallel to a nearby fault (fig. 2, no 10). Other manganiferous veins within and near the study area have been described previously. At the Black Raven prospect, outside the study area about 1 mi north-northeast of the Northrup prospect, veins containing manganese-oxide minerals and black calcite occupy a fault zone in volcanic rocks (Trask, 1950, p. 193). Manganese-oxide-bearing veins have also been reported within brecciated granite near the northwest corner of the study area (SW¼ sec. 7, T. 8 N., R. 1 E.,) (Dorsey, 1956a). Additional veins containing manganese-oxide minerals were observed during this study. None of the manganiferous veins within and near the study area are large enough to contain resources of manganese under present or foreseeable future market conditions.

Three alluvial samples collected from drainages with placer claims in the northwestern and southwestern parts of the study area contained only traces of gold.

Sand and gravel is plentiful in and near the study area and has been extracted mainly for use in highway construction from numerous pits north and east of the study area. Sources outside the study area should satisfy local and regional demand in the foreseeable future.

Stone has been produced from four quarries outside the northeast end of the study area. During the 1950's, light-gray felsite was quarried for road metal from two pits 1.5 mi southwest of Newberry Springs (fig. 2, no. 8). Outcrops of similar rock extend southward into the study area. Two active quarries 1.7 and 2.0 mi southeast of Newberry Springs exploit a body of bright red porphyritic dacite or quartz latite. This type of rock is not found in the study area. During August, 1986, the Santa Fe Railroad began site development for a ballast quarry to be located 0.4 mi north of the study area in NW¼ SW¼ sec. 5, T.8N., R.3E. Rocks at the quarry site consist mostly of extrusive andesite and dacite; similar rocks are widespread in the study area.

Rodman Mountains Wilderness Study Area

Nine mines and prospects and one placer gold occurrence in and near the Rodman Mountains Wilderness Study Area were examined for this study (table 2). There are no active mines within the study area. However, the Red Top Flat mine (fig. 2, no. 18) was producing volcanic cinder in 1984 and contains approximately 12 million tons of reserves that lie entirely outside the study area. The Flying M Association claim group (fig. 2, no. 20) was being explored for placer and lode gold in 1984; the mineral occurrences at this property do not extend into the study area.

Three prospects in the southwestern part of the study area expose gold-bearing quartz and barite veins, and a siliceous dike (fig. 2, nos. 17, 19, and 21). The veins are discontinuous and the dike is poorly exposed. Resources were not identified due to the limited surface exposures, but further study of these prospects is warranted.

An alluvial sample from a stream-terrace deposit near the east margin of the study area (fig. 2, no. 15) contains an anomalous gold concentration of 0.0165 oz/yd^3. Placer gold has not previously been recognized in this area. The total volume of alluvium within this deposit probably is about 300,000 yd^3, and additional terrace gravels are present nearby. Sampling was not adequate to determine average gold values, but the high concentration of gold in the single reconnaissance sample suggests that more detailed sampling might delineate placer resources at this site.

Conclusions

No mineral resources were identified within either of the study areas. Manganiferous veins within the Newberry Mountains Wilderness Study Area are too small to constitute mineral resources under present or foreseeable future market conditions. Occurrences of lode gold, silver, and copper in the southwestern part of the Rodman Mountains Wilderness Study Area, and of placer gold near the east margin of the study area, warrant further study.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Brett F. Cox, Andrew Griscom, James E. Kilburn, Gary L. Raines, and Daniel H. Knepper, Jr., U.S. Geological Survey

Geology

The Newberry and Rodman Mountains are underlain chiefly by Jurassic and Cretaceous plutonic rocks and by Miocene volcanic and sedimentary rocks (fig. 2). The plutonic rocks locally contain pendants of gneiss, metasedimentary rocks, and metavolcanic rocks. The region was disrupted by normal faulting in middle Cenozoic time and by strike-slip faulting in late Cenozoic time.

Rock Units

Outcrops of prebatholithic rocks are relatively sparse in the region, and none were mapped in the Rodman Mountains Wilderness Study Area. A small pendant of Precambrian gneiss lies astride the west margin of the Newberry Mountains Wilderness Study Area. Metasedimentary rocks of Paleozoic or early Mesozoic age apparently are absent from both study areas, but a small body of marble crops out in Kane Wash between the study areas. Mesozoic metavolcanic rocks, termed the Ord Mountain Group by Gardner

(1940), form small bodies in the southwestern and northeastern parts of the Newberry Mountains Wilderness Study Area and a large pendant exposed north and south of Kane Wash between the two study areas. These metavolcanic rocks consist predominantly of silicic to intermediate flows and shallow intrusive bodies. Recent geochronologic and regional stratigraphic studies suggest that the metavolcanic rocks are mostly Triassic but locally include Jurassic rocks (Karish, 1983; Walker, 1985).

Mesozoic plutonic rocks in the region represent a southward continuation of the Sierra Nevada batholith. The plutonic rocks underlie most of the Rodman Mountains Wilderness Study Area and form several isolated outcrops surrounded by Miocene rocks and Quaternary alluvium in the Newberry Mountains Wilderness Study Area. Four main plutonic lithologies are present (fig. 2; plutonic rock nomenclature after Streckeisen, 1976). First, dark-gray diorite, including minor quartz diorite, forms numerous small bodies that locally intrude gneiss and metavolcanic rocks and that are in turn intruded by younger plutons. Several masses of diorite are present in the northwestern part of the Newberry Mountains Wilderness Study Area. Second, medium-gray coarse-grained quartz monzonite underlies a large area including the western third of the Rodman Mountains Wilderness Study Area. The quartz monzonite is also abundant in the Ord Mountains and Fry Mountains southwest of the Camp Rock fault. Locally, the quartz monzonite is intruded by north-trending dikes composed of weakly metamorphosed fine-grained mafic rocks (not shown on fig. 2). The third type of plutonic rock consists of leucocratic syenogranite, which is particularly abundant in the Newberry Mountains Wilderness Study Area. Along the north flank of the Newberry Mountains, this rock unit consists of colorful, pink, coarse-grained rocks that are strongly fractured and brecciated; by contrast, the two outcrops on the south flank of the range are generally finer grained, drab gray or tan, and relatively unfractured. Finally, light-gray, medium-grained monzogranite forms an extensive north-trending belt that includes the eastern third of the Rodman Mountains Wilderness Study Area. Similar rocks are locally exposed along Kane Wash south of the Newberry Mountains Wilderness Study Area.

Dating by the Ar^{40}/Ar^{39} method in the Fry Mountains (Karish, 1983) indicates that the quartz monzonite unit and rocks resembling those in the diorite unit are Jurassic in age and that the monzonite unit is Late Cretaceous in age. The age of the syenogranite in the Newberry Mountains is uncertain, but similar rocks in the east-central Mojave Desert have yielded Jurassic ages.

Miocene volcanic and sedimentary rocks overlie the batholithic and prebatholithic rocks throughout most of the Newberry Mountains Wilderness Study Area and extend eastward across the northern end of the Rodman Mountains Wilderness Study Area. A lobe of Miocene strata that is largely hidden beneath flows of Pleistocene basalt extends southward across the central part of the Rodman Mountains Wilderness Study Area. The volcanic and sedimentary rocks are lithologically diverse (Dibblee, 1964a, b, 1970; Dibblee and Bassett, 1966; Cox, 1986), but in this report they are consolidated into a single map unit (fig. 2). They consist of a lower stratigraphic sequence rich in volcanic rocks and an upper sequence composed mostly of sedimentary rocks.

The lower, volcanogenic, sequence forms most of the crest and north flank of the Newberry Mountains and also crops out in the northeastern part of the Rodman Mountains Wilderness Study Area. The lower part of this sequence consists mostly of extrusive rhyolite and volcanic debris-flow breccia and locally contains dikes and flows of andesite and dacite. These rocks are unconformably overlain by extrusive basalt, andesite, dacite, and rhyolite, with interlayered conglomerate, sedimentary breccia, and minor lapilli tuff. A basalt flow yielded an early Miocene (23.1±2.3 Ma) potassium-argon age (Nason and others, 1979).

The upper sequence of volcanic and sedimentary rocks is largely restricted to the southern fringe of the Miocene outcrop belt, and its youngest parts lap depositionally onto pre-Cenozoic rocks along the northern edge of the Ord and Rodman Mountains. Unconformities are present within it and locally at its base. The sequence consists predominantly of conglomerate, sedimentary breccia, and pebbly sandstone, and it also contains minor amounts of pumiceous air-fall tuff, as well as a distinctive layer of ash-flow tuff near Kane Wash, which Glazner and others (1986) have correlated with the Peach Springs Tuff of Young and Brennan (1974). The ash-flow tuff near Kane Wash has been dated at 21±1.0 Ma by the fission-track method (Dokka, 1980). Radiometric ages for the Peach Springs Tuff and correlative units in other ranges seem to indicate an age of 19 Ma (Glazner and others, 1986).

Dikes of aphanitic to fine-grained porphyritic rocks intrude the lower sequence of volcanic and sedimentary rocks in the eastern part of the Newberry Mountains Wilderness Study Area and near the mouth of Box Canyon immediately northeast of the Rodman Mountains Wilderness Study Area. Most of these intrusions are rhyolitic to dacitic in composition, but dikes of andesite and basalt are also present in smaller amounts. In addition, geophysical studies (this report) suggest that a large Tertiary stock or plug is concealed beneath surficial rocks and sediments at the east end of the Newberry Mountains Wilderness Study Area and northwest end of the Rodman Mountains Wilderness Study Area. None of the Tertiary intrusive rocks within the Newberry Mountains have been dated radiometrically, but intrusive relations and compositional similarities with extrusive volcanic rocks in the range suggest that they are early Miocene in age. A large felsic intrusion at the southeast corner of the map area (fig. 2) yielded a potassium-argon age of approximately 24 Ma (R.K. Dokka, oral commun., 1986).

Quaternary basalt flows and alluvium underlie a relatively small part of the two study areas. The basalt erupted from vents near the south boundary of the Rodman Mountains Wilderness Study Area and flowed northwest to Kane Wash. A cinder cone that formed in the vent area is the site of an active mining operation; however, this cinder cone lies outside the study area. Previous studies have shown that the basalt is alkalic (Wise, 1969, table 1, sample 6) and was erupted during the Pleistocene, approximately 0.6 Ma

(W. B. Bull, oral commun., 1986). A northwest-trending fault that cuts the basalt near the cinder cone (fig. 2) may have served as a conduit for the eruptions.

Quaternary alluvium in the two study areas consists of sand and gravel deposited in stream canyons and on alluvial fans. The deposits range widely in age, but only one generalized unit is shown on the map.

Geologic Structure

In common with adjacent areas of the Mojave Desert to the north and east, the Newberry and Rodman Mountains were subjected to an intense episode of northeast crustal extension contemporaneous with early Miocene volcanism and sedimentation between about 23 and 21 Ma (Dokka, 1986; Dokka and Woodburne, 1986). The main structural features of this deformational event have been established by previous work (Dokka, 1980, 1983, 1986; Dokka and Glazner, 1982). Geologic mapping conducted during the present study confirms the main structural interpretations of this previous work, while clarifying stratigraphic relations within the Miocene section and providing more detailed information on the nature of Miocene and younger faulting. The main structural features produced by early Miocene crustal extension are (1) the Newberry Mountains detachment fault (Dokka, 1980, 1986; Dokka and Glazner, 1982) separating Miocene strata from underlying plutonic rocks, (2) the Kane Springs fault (Dokka, 1980, 1986; Dokka and Glazner, 1982), which forms the abrupt southern boundary of the extensional complex, and (3) abundant north- and northwest-trending faults that cut Miocene strata and that locally cut pre-Cenozoic basement rocks.

The basal contact of the Miocene rocks was originally interpreted to be a major buttress unconformity with many thousands of feet of paleorelief (Dibblee, 1970, 1971), but more recently it has been shown to be a detachment fault that separates highly extended Miocene rocks in the upper plate from relatively unextended pre-Cenozoic rocks of the lower plate (Dokka, 1980; Dokka and Glazner, 1982). Syenogranite on the footwall of the Newberry Mountains detachment fault is shattered in a zone of indurated, hematite-stained breccia and cataclasite several hundred feet thick. Cataclasis of the syenogranite is especially pronounced in the northwestern part of the Newberry Mountains Wilderness Study Area. By contrast, the two outcrops of syenogranite on the south flank of the Newberry Mountains are not cataclastically deformed, and the westernmost of these two outcrops locally is depositionally overlain by the lower unit of Miocene volcanic and sedimentary rocks. Therefore, these southern two outcrops of plutonic rocks apparently lie within the upper plate of the detachment fault, as implied by Dokka and Glazner (1982, fig. 3). Hematite that coats fractures in the breccia and cataclasite probably was introduced by hydrothermal fluids; however, no other evidence of alteration or mineralization was observed in association with the detachment fault.

The extended terrane is bounded on the south by the east-trending Kane Springs fault, which has been interpreted as a right-lateral strike-slip or oblique-slip transform fault that marks an abrupt transition to a region of no extension south of the fault (Dokka, 1980, 1983, 1986; Dokka and Glazner, 1982). The Kane Springs fault is well exposed in the northern and northeastern parts of the Rodman Mountains, where it appears from the map pattern to dip gently to steeply northward. The fault is largely concealed along the north side of Kane Wash, where it is overlain by gently dipping, relatively unfaulted conglomerate, sandstone, and ash-flow tuff that form the largely post-kinematic upper sequence of Miocene volcanic and sedimentary rocks (Dokka, 1980; Dokka and Glazner, 1982). Geologic mapping for the present study revealed that the segment of the fault along Kane Wash locally has been reactivated as a south-vergent thrust or reverse fault, possibly related to late Cenozoic development of the Camp Rock and Calico fault systems. No evidence of mineralization was observed in association with the Kane Springs fault.

The Miocene volcanic and sedimentary rocks are tilted and extended along many north- and northwest-trending, moderately to steeply dipping, normal and oblique-slip faults that have their east sides displaced relatively downward. Mapping for this study revealed that these faults are particularly abundant in the north-central and northeastern parts of the Newberry Mountains. Some of the faults are restricted to the upper plate of the Newberry Mountains detachment fault, whereas others cut and offset the detachment fault (Dokka and Glazner, 1982). In the central and northern parts of the Newberry Mountains Wilderness Study Area, arcuate northwest-trending faults systematically truncate and offset north-trending faults (fig. 2). These arcuate faults terminate southeastward against a north-trending fault that is antithetic, that is, its east side is displaced relatively upward rather than downward, causing the reappearance of pre-Cenozoic rocks and the Newberry Mountains detachment fault in the northeastern part of the study area. Both this antithetic fault and the Newberry Mountains detachment fault are intruded by silicic dikes, indicating that intrusive activity continued after movement on the detachment fault and high-angle faults had ended. Many of the north- and northwest-trending faults are lined with veins composed of calcite and manganese-oxide minerals; these veins are discussed in the following section on rock alteration and veining.

The late Cenozoic tectonic development of the Newberry and Rodman Mountains region has been dominated by right-lateral displacements on the Camp Rock and Calico faults. These two structures belong to a larger family of northwest-trending wrench faults that traverse the Mojave Desert region (Jennings, 1975). The Camp Rock and Calico faults offset the Kane Springs fault and other structures related to early Miocene extensional deformation. Based on this, and on observed offsets of pre-Cenozoic rock units, previous workers have proposed that the total displacements on the Camp Rock and Calico faults near the Newberry and Rodman Mountains are approximately 1 to 2.5 mi and 5 to 6 mi, respectively (Hawkins, 1976; Miller, 1980; Dokka, 1983). These estimates are generally confirmed by geologic and geophysical evidence from this study. Although the faults are post-early Miocene, the more precise onset of faulting is uncertain (Dokka, 1983). The Camp Rock and Calico faults have both been active during Quaternary time, and the Calico fault has been active recently, as indicated by scarps in Holocene alluvium east of the Newberry Mountains.

Rock Alteration and Veins

Pre-Cenozoic and Cenozoic hydrothermal activity potentially related to mineralizing systems has locally involved the following processes in and near the Newberry and Rodman Mountains Wilderness Study Areas: (1) albitization of plutonic rocks, (2) potassium metasomatism of Miocene volcanic rocks, (3) argillic alteration of Miocene basalt, (4) concentrations of limonitic minerals, and (5) formation of veins. Propylitic alteration of Miocene andesite and basalt is present locally, but it is generally minor and is not included in the following discussion.

Jurassic quartz monzonite is pervasively albitized to grayish-white rock within a large irregular zone that includes the southwest corner of the Rodman Mountains Wilderness Study Area (fig. 3). The affected rocks are strongly jointed and form angular outcrop surfaces. Primary potassium feldspar is almost totally replaced and primary plagioclase (andesine to sodic labradorite) is partly replaced by albite or sodic oligoclase in as much as 75 percent of the quartz monzonite in this zone. Associated mineralogical effects include partial to complete alteration of hornblende and biotite to actinolite, epidote, and sphene. Small areas of albitized quartz monzonite are common north of the zone mapped on figure 3, but these are largely restricted to the immediate vicinity of joints and fractures.

Similar albitization affected Jurassic plutonic rocks over a broad region of the central and eastern Mojave Desert (Allen and others, 1983; Karish, 1983; Miller and others, 1985; Fox, 1985). The albitization may have been caused by a late Mesozoic episode of hydrothermal activity that has been identified in part of this region on the basis of anomalous oxygen-isotope ratios in Jurassic and older rocks (Solomon and Taylor, 1981). The possible relation between albitization and regional patterns of mineralization is uncertain and warrants future study.

Several mineral occurrences near the southwest corner of the Rodman Mountains Wilderness Study Area lie near the margins of the zone of albitized quartz monzonite and may be genetically related to it. Four prospects (fig. 2 and table 2, nos. 17, 19, 20, and 21) expose veins and altered rocks containing copper minerals and anomalous concentrations of gold and silver. Albitized quartz monzonite sampled farther east and about 0.5 mi south of the study area contains anomalous concentrations of copper, lead, and molybdenum (fig. 4). Similar albitized plutonic rocks are present in the deep root zone of the Yerington porphyry-copper deposit in western Nevada (Carten, 1981). The albitized quartz monzonite and associated mineral occurrences near the southwest corner of the Rodman Mountains Wilderness Study Area may likewise have formed deep within a hydrothermal circulation system.

Potassium metasomatism of variable intensity affects many volcanic rocks in a large area that is approximately coextensive with the belt of Miocene intrusions near the east end of the Newberry Mountains Wilderness Study Area (fig. 3). Field observations suggest that alteration is most abundant and intense in the northeastern half of this area. Similar alteration is associated with intrusive rocks in a smaller area directly northeast of the Rodman Mountains Wilderness Study Area (Sanner, 1985, p. 20). The rocks most affected consist of intrusive rhyolite to dacite; however, extrusive basalt, andesite, and dacite located near the intrusive bodies also are similarly altered to varying degrees. Typically, the altered intrusive rocks are grayish red with light-gray mottles and are strongly enriched in potassium, containing K_2O concentrations ranging from 7.6 to 11.6 percent. By comparison, unaltered intrusive rocks within the altered zone are light to medium brown, gray, or pinkish gray and contain less than 5 percent K_2O. The excess potassium in the altered rocks resides in secondary potassium feldspar that replaces both phenocrystic and groundmass plagioclase. The groundmass commonly also contains abundant secondary quartz and fine-grained opaque material. Some of the altered intrusive rocks are strongly brecciated, possibly in part owing to hydrothermal processes.

Similar potassium metasomatism affects Miocene volcanic and sedimentary rocks in the southeastern Cady Mountains 15 to 20 mi east of the Newberry Mountains (Hewett, 1964; Glazner, 1980; Chapin and Glazner, 1983; Bartley and Glazner, 1985) and in the southwestern Calico Mountains about 15 mi to the northwest (Darby Fletcher, oral commun., 1986). Two aerial gamma-ray spectrometer surveys (U.S. Bureau of Land Management, unpub. data, 1978; High Life Helicopters, Inc., 1980) indicate potassium concentrations 2 to 3 times higher than regional background values in each of these areas in the Newberry, Cady, and Calico Mountains, and also in a fourth area near Mt. General about 6 mi northwest of Barstow. Data from these surveys were used to help define the limits of the altered zone in the Newberry Mountains, as mapped on figure 3.

The strongest aerial potassium anomaly in the central Mojave Desert region is centered on the area of historical silver mining in the Calico Mountains (Weber, 1967; Dibblee, 1970). Similarly, the potassium anomaly near Mt. General is located near a prospect containing a silver occurrence (Bowen, 1954, pl. 2). Broad zones of potassium metasomatism are spatially associated with epithermal ore deposits in other regions, such as those surrounding the silver-base metal deposits in the Creede mining district of southwest Colorado (Bethke and others, 1976; P.B. Barton, Jr., oral commun., 1986). These comparisons suggest that potassium metasomatism may be a useful guide when prospecting for epithermal mineral deposits in the central Mojave Desert region. Areas that contain extensive potassium-feldspar alteration but that have little or no mining history, such as the northeastern Newberry Mountains and southeastern Cady Mountains, may warrant further investigation for evidence of mineralization. Evidence of possible

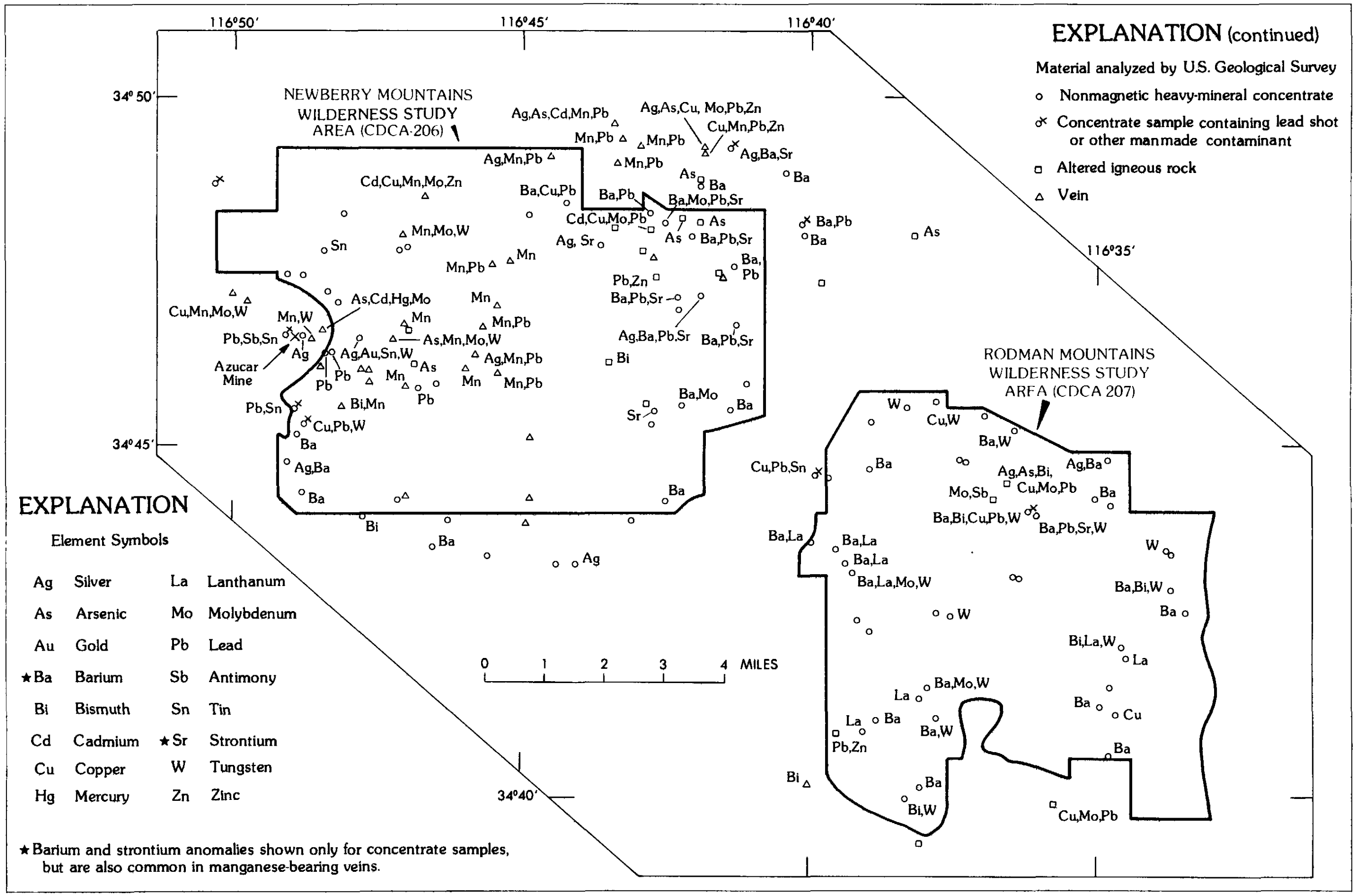


Figure 4. Map showing geochemical sample sites and geochemical anomalies in the Newberry Mountains and Rodman Mountains Wilderness Study Areas.

epithermal silver mineralization at the east end of the Newberry Mountains Wilderness Study Area is discussed in the geochemistry section of this report.

A zone of argillic alteration within basalt lies along a large northwest-trending fault in the southwestern part of the Newberry Mountains Wilderness Study Area (fig. 3). The altered basalt within this zone consists of friable light-gray rock that contrasts sharply with indurated dark-gray basalt exposed immediately outside the zone. The zone of alteration cuts sharply across layering in a thick sequence of basalt flows. An unidentified clay mineral has replaced plagioclase crystals and lines vesicles in the rock. The altered basalt is a possible target for future mineral exploration because it lies at the southeast end of a belt of mineralized rocks defined by quartz and calcite veins, geochemical anomalies, and a gold-silver prospect at the Azucar mine (zone A on fig. 2).

Bedrock outcrops containing anomalous concentrations of limonitic minerals (ferric-oxide, ferric-sulfate, and ferric-carbonate minerals) were identified on Landsat multispectral-scanner images using a color-ratio compositing technique described by Rowan and others (1974). These areas were field checked, and four areas within or near the two study areas showed evidence of hydrothermal alteration (fig. 3). The boundaries of the areas containing limonite are only approximately located because of the small scale (1:800,000) of the original Landsat images. A fifth area containing limonite was identified during geologic mapping for this report.

One area of limonitic alteration straddles the western border of the Newberry Mountains Wilderness Study Area, directly east of the Azucar mine, and coincides with part of mineral resource zone A. Rocks near the center of this area contain calcite veins in propylitically altered andesite and basalt. A second area lies within metavolcanic rocks west of the Rodman Mountains Wilderness Study Area and directly south of the former L & L mine. A third area lies within quartz monzonite in the southwestern part of the Rodman Mountains Wilderness Study Area and is included within mineral resource potential zone C. Chloritization of mafic minerals and albitization and weak sericitization of feldspar were observed in this area. A fourth area lies directly east of the Rodman Mountains Wilderness Study Area. This area was field checked in its eastward extension, outside the mapped area of figure 2 and directly south of Silver Bell mine. There, andesitic and basaltic rocks show signs of weak propylitic alteration and contain veins of black calcite. The fifth area of limonitic alteration forms a narrow northwest-trending band within quartz monzonite in the north-central part of the Rodman Mountains Wilderness Study Area, and lies within the northwestern part of mineral resource potential zone D.

Several types of veins are present in rocks of the study areas. Pre-Cenozoic rocks locally contain monomineralic veins of white or colorless quartz. Such veins were observed in plutonic rocks located at the Azucar mine and in the southwestern and north-central parts of the Rodman Mountains Wilderness Study Area (zones A, C, and D on fig. 2). Quartz veins in these areas and in neighboring ranges to the south and west locally contain anomalous amounts of gold, silver, and copper.

The Miocene rocks exposed throughout the Newberry Mountains Wilderness Study Area and in the northern part of the Rodman Mountains Wilderness Study Area contain veins of calcite, manganese-oxide minerals, chalcedony, and opal. Some of these veins contain minor amounts of quartz, which typically originated by recrystallization of fibrous chalcedony. Most abundant are manganiferous veins composed mostly of calcite and manganese-oxide minerals including pyrolusite and psilomelane. Locally, these veins contain anomalous concentrations of silver and several other metals (see geochemistry section). Manganiferous veins are most abundant along north- and northwest-trending faults and fractures that cut moderately tilted Miocene strata in the central and northeastern Newberry Mountains and northeastern Rodman Mountains. The richest concentrations of manganese-oxide minerals were observed adjacent to a northwest-trending fault in the general vicinity of the Northrup prospect (fig. 2, no. 10). Manganiferous veins were not seen in the relatively undisturbed flat-lying strata that form the upper sequence of volcanic and sedimentary rocks along Kane Wash and in the northeastern Rodman Mountains. Sparse veinlets of manganese-oxide minerals are also present in brecciated pink syenogranite in the northwestern Newberry Mountains.

Manganiferous veins in the upper-plate rocks typically consist of "black calcite" (Hewett and Radtke, 1967) darkened by disseminated fine-grained inclusions of manganese-oxide minerals (1 to 10 percent by volume). Layers of black calcite commonly alternate with layers of either white calcite or relatively pure manganese-oxide minerals, resulting in prominent banding parallel to vein margins. Chalcedony and quartz are present in some of the veins, where they commonly have formed interstitial to, or as replacements of, black calcite that crystallized earlier. Barite crystals locally are associated with the chalcedony and quartz and rarely form thin monomineralic barite veins. The largest manganiferous veins are several feet thick and several hundred feet long.

The manganiferous veins probably were precipitated by ascending low-temperature hydrothermal fluids. Episodes of vein brecciation and shearing commonly alternated with episodes of vein growth; this, together with apparent restriction of the veins to the older tilted rock sequences, suggests that the veins developed synchronously with faulting of the upper-plate rocks. Thus, the episode of hydrothermal activity that produced the manganiferous veins may have been coeval with the brief period of early Miocene crustal extension that occurred between about 23 and 21 Ma.

Grayish-white aphanitic veins consisting of opal or chalcedony and variable amounts of fine-grained calcite and other carbonate minerals were observed along several faults near the south and west margins of the Newberry Mountains Wilderness Study Area. These veins contain little or no field or geochemical evidence of metallic mineralization. They apparently are quite young, as some of them cut older Quaternary alluvium at the northwest corner of the Newberry Mountains

Wilderness Study Area.

Geochemical Studies

Methods

Reconnaissance geochemical studies were conducted to help determine the nature, location, and intensity of ore-forming processes in the study areas. Samples included altered rocks, veins, and heavy-mineral concentrates from stream sediments. Sandy alluvium was reduced to a nonmagnetic heavy-mineral concentrate by hand panning, heavy-liquid immersion, and electromagnetic separation. Each concentrate sample was split into two parts: one for spectrographic analysis and the other for mineralogical studies. All rock and concentrate samples were analyzed for 30 elements using a semiquantitative emission-spectrographic method (Grimes and Marranzino, 1968). Vein samples rich in carbonate and manganese-oxide minerals were diluted with a mixture of aluminum oxide, potassium carbonate, and silica prior to spectrographic analysis. Some samples collected from veins and altered rocks were also analyzed for gold by an atomic absorption method (Ward and others, 1969) and for tungsten by an induction-coupled plasma method. The analytical results obtained for the stream-sediment concentrate samples were presented by Detra and Kilburn (1985). The locations of all vein, rock, and concentrate geochemical samples are shown on figure 4; anomalous concentrations of ore-forming and pathfinder elements are indicated by element symbols adjacent to the sample sites.

Summary of Results

Anomalous concentrations of metallic and nonmetallic elements in altered rocks, veins, and stream-sediment concentrate samples confirm that both study areas contain mineralized rocks. Arsenic, barium, gold, molybdenum, and silver geochemical anomalies are clustered within two zones near the west and east ends of the Newberry Mountains Wilderness Study Area; in addition, widespread manganiferous veins in the western and central parts of the study area contain anomalous concentrations of copper, lead, molybdenum, silver, tungsten, and zinc. The data indicate that epithermal mineralization of variable intensity has occurred in much of the Newberry Mountains Wilderness Study Area. Barium and tungsten anomalies are widespread in the Rodman Mountains Wilderness Study Area and are locally accompanied by bismuth, copper, lanthanum, lead, molybdenum, and silver anomalies. These geochemical anomalies are attributed to widespread quartz veins, to minor small bodies of mineralized skarn, and to lanthanum-bearing heavy minerals disseminated in quartz monzonite.

Newberry Mountains Wilderness Study Area

An east-trending arcuate zone astride the west margin of the Newberry Mountains Wilderness Study Area contains arsenic, cadmium, gold, mercury, molybdenum, silver, and tungsten geochemical anomalies (zone A on fig. 2; fig. 4). The most intense anomalies are in stream-sediment concentrates, including a silver anomaly of 1,000 parts per million (ppm) near the Azucar mine and a 700-ppm gold anomaly in the central part of the zone. An anomalous concentration of arsenic (22 ppm) was detected in argillically altered basaltic rocks near the east end of the zone. Concentrations of 500 ppm arsenic, 650 ppm molybdenum, and 25 ppm tungsten were measured in veinlets of manganese-oxide minerals within dacite flow-breccia directly north of the area of argillized basalt. A concentration of limonitic minerals was identified from Landsat images where zone A crosses the western boundary of the study area (fig. 3). Two samples of black calcite were collected from veins in this limonitic area: one sample contains 20 ppm tungsten; the other contains 37 ppm arsenic, 1.9 ppm cadmium, 1.2 ppm mercury, and 7 ppm molybdenum. Directly west of the limonitic area, U.S. Bureau of Mines personnel found small amounts of gold and silver in a quartz vein at the Azucar mine (table 1).

Although the geochemical anomalies detected in veins and altered rocks provide clear indications of hydrothermal activity and localized mineralization within zone A, the type and intensity of mineralization is uncertain because of ambiguities in the interpretation of the stream-sediment-concentrate geochemistry. The concentrate samples that contain gold and silver anomalies were collected in small drainage basins underlain largely by coarse-grained Miocene conglomerate. The rock detritus in the conglomerate was derived from pre-Cenozoic plutonic and metavolcanic rocks located near Ord Mountain, where there are abundant veins containing gold, silver, and copper minerals in a gangue of quartz and barite (Weber, 1963). Veins and metasomatic replacement bodies containing scheelite are also located near Ord Mountain. The age of mineralization in the Ord Mountain area has not been determined, but it may be Mesozoic and therefore older than the Miocene conglomerate in the Newberry Mountains. For these reasons, all of the anomalous concentrations of barium, bismuth, copper, gold, lead, silver, tin, and tungsten found in concentrates near the south and west margins of the Newberry Mountains Wilderness Study Area are suspect, and may merely reflect the detrital mineralogy of conglomeratic rocks derived from mineralized rocks near Ord Mountain.

As an additional complication, the geochemical anomalies in rocks and veins within zone A may reflect the combined effects of two unrelated episodes of mineralization. At the Azucar mine, monomineralic quartz veins are present in Mesozoic plutonic rocks, whereas the eastern two-thirds of the zone contains veins of calcite and manganese-oxide minerals in argillically and propylitically altered Miocene volcanic rocks. Quartz veins similar to those at the Azucar mine are common in pre-Cenozoic rocks over a broad region south of the Newberry Mountains, and they may be Mesozoic, rather than Tertiary, in age. Because vein occurrences of gold and silver in zone A have been found only at the Azucar mine, and because the gold and silver detected in stream-sediment concentrates may be recycled from Miocene conglomerate, the existence of epithermal gold or silver occurrences in Miocene rocks in the eastern part of zone A remains in doubt.

A cluster of geochemical anomalies found in stream-sediment concentrates at the east end of the Newberry Mountains Wilderness Study Area includes numerous barium anomalies (10,000 ppm or greater) accompanied in many drainages by lead (3,000 to 30,000 ppm) and strontium (1,500 to 7,000 ppm) anomalies, and in three drainages by silver anomalies (1, 20, and 50 ppm). Microscopic examination of concentrate samples showed abundant barite as the source of the barium anomalies; the strontium anomalies probably reflect impurities contained within barite. The barite may be derived from abundant manganese-oxide-bearing veins and sparse, narrow, monomineralic barite veins that are present in this part of the Newberry Mountains. Conglomerate containing detritus of pre-Cenozoic rocks is absent from this area, so most of the stream-sediment anomalies probably can be attributed to in situ mineralization. The distribution of the anomalies correlates generally with the outcrop area of Miocene intrusive rocks (fig. 2) and with the zone of widespread potassium metasomatism (fig. 3) near the northeast end of the Newberry Mountains. Several samples collected from veins and altered rocks in this area contain anomalous concentrations of arsenic, cadmium, copper, lead, molybdenum, silver, and zinc.

The spatial association of barium, lead, and silver geochemical anomalies, silicic intrusive rocks, and potassium metasomatism also occurs in mineralized parts of the Calico Mountains about 15 mi to the northwest. However, in the Calico district, veins and disseminated deposits contain silver minerals in a gangue of abundant jasper and barite and minor amounts of manganese-oxide minerals (Weber, 1967). Veins in the Newberry Mountains consist mostly of calcite and manganese-oxide minerals; thick veins of barite and jasper containing silver minerals have not been observed. Therefore, the analogy with the Calico district is limited to gross similarities of geochemistry and rock alteration and is not reinforced by more direct evidence of mineralization.

Veins composed of manganese-oxide minerals and manganiferous black calcite were sampled in the western, central, and northern parts of the Newberry Mountains Wilderness Study Area. These veins locally contain anomalous amounts of various elements, with the maximum concentrations as follows: arsenic, 500 ppm; barium, greater than 10,000 ppm; copper, 210 ppm; lead, 250 ppm; manganese, greater than 10,000 ppm; molybdenum, 650 ppm; silver, 39 ppm; strontium, 3,200 ppm; tungsten, 210 ppm; and zinc, greater than 2,000 ppm. Atomic-absorption analyses did not detect gold in any of the vein samples. Anomalous concentrations of silver and other metals in epithermal veins of manganese-oxide minerals and black calcite have been noted in numerous mining districts in the western United States (Hewett, 1964; Hewett and Radtke, 1967), and in some cases the manganese-oxide minerals have actually been mined as silver ore (Cousins, 1984; Heyl and others, 1973, p. 593-594). None of the vein-related geochemical anomalies in the Newberry Mountains Wilderness Study Area are large enough to imply mineral-resource potential. However, the anomalies indicate widespread low-grade epithermal mineralization that previously was not recognized in the study area.

Rodman Mountains Wilderness Study Area

The stream-sediment-concentrate geochemical data for the Rodman Mountains Wilderness Study Area indicate anomalous concentrations of several elements, with the maximum concentrations as follows: barium, greater than 10,000 ppm; bismuth, 1,000 ppm; copper, 200 ppm; lanthanum, 2,000 ppm; lead, 10,000 ppm; molybdenum, 30 ppm; silver, 10 ppm; and tungsten, 7,000 ppm. The barium and tungsten anomalies are abundant and widespread, whereas anomalous concentrations of other elements are more localized. Optical examination of the concentrate samples revealed that barite and scheelite are the sources of the barium and tungsten anomalies, respectively. Other common heavy minerals in the samples include rutile, sphene, anatase, apatite, andalusite, and zircon. Heavy minerals present in minor amounts include monazite, fluorite, tourmaline, and hematite. In addition, lead shot was identified as a contaminant in two of the three samples having anomalous lead concentrations.

By analogy with known occurrences of mineralized rocks within and near the study area (for example, see Weber, 1963), the minerals barite and scheelite, and the isolated bismuth, copper, molybdenum, and silver anomalies, probably are derived largely from widespread quartz veins in the quartz monzonite and monzogranite units. Skarn associated with small isolated masses of calcareous metasedimentary rocks engulfed by the plutonic rocks probably is the source of some of the tungsten, bismuth, and molybdenum anomalies; small inclusions of metasedimentary rock were observed at several locations, and the identification of the contact-metamorphic mineral andalusite in the heavy-mineral concentrates suggests that such inclusions may be fairly common.

A cluster of geochemical anomalies is associated with zone D in the north-central part of the study area (figs. 2 and 4). Sheared and mineralized quartz monzonite at a prospect near the northwest margin of the zone contains anomalous amounts of arsenic (24 ppm), bismuth (182 ppm), copper (greater than 20,000 ppm), lead (7,000 ppm), molybdenum (1,000 ppm) and silver (100 ppm). U.S. Bureau of Mines personnel found concentrations of copper and silver in a quartz vein at this same prospect (table 2, no. 14). A narrow northwest-trending band of limonite-stained quartz monzonite about 0.4 mi southwest of this prospect (fig. 3) is slightly enriched in antimony (7 ppm) and molybdenum (10 ppm). Two stream-sediment concentrates collected near the center of zone D contained anomalous concentrations of bismuth (150 ppm), lead (5,000 and 10,000 ppm), and copper (150 ppm), in addition to barium (greater than 10,000 ppm) and tungsten (1,000 and 2,000 ppm). The bismuth, lead, and copper anomalies are suspect, however, because lead shot was identified in one of the two concentrate samples. Finally, a stream-sediment concentrate collected about 0.8 mi downstream and to the northeast of the zone contains an anomalous concentration of silver (10 ppm). This cluster of geochemical anomalies in rocks and stream-sediment concentrates indicates that hydrothermal processes locally caused some accumulation of silver, copper and other metals in zone D, although it is not clear from the geochemical data whether resources have accumulated anywhere in the zone. Several stream-sediment concentrates collected within and near zone C at the southwest corner of the study area contain little evidence of mineralization, despite the presence of several prospects within the zone (table 1b, nos. 17, 19, 20, 21).

Lanthanum anomalies are spatially associated with the quartz monzonite unit in the western part of the study area. Outcrops of Miocene conglomerate in the southeastern part of the study area are composed almost exclusively of detritus from the quartz monzonite unit. This may explain the two isolated lanthanum anomalies to the east of and downstream from the conglomerate outcrops. The lanthanum anomalies are attributed to monazite, a rare-earth phosphate mineral that was identified in the concentrate samples. In addition to lanthanum and other rare-earth elements, monazite typically contains substantial amounts of thorium (Clark and others, 1966, table 24-5). Therefore, monazite may also be responsible for elevated thorium values (as much as 2 to 3 times regional background) measured over the quartz monzonite unit by an aerial gamma-ray survey (High Life Helicopters, Inc., 1980, flight lines 16 and 17). The monazite may be disseminated as an accessory mineral within the quartz monzonite, or it may occur in sparse pegmatitic lenses that were observed within the quartz monzonite. Although monazite can be an important ore mineral in certain geologic settings, occurrences in normal granitic rocks and pegmatite bodies are rarely concentrated enough to be viable sources of either rare-earth minerals or thorium. Therefore, no mineral-resource significance is inferred for monazite in the Rodman Mountains Wilderness Study Area.

Geophysical Studies

Gravity Survey

Gravity data for the vicinity of the Newberry and Rodman Mountains were obtained from published sources (Oliver and others, 1980; Roberts and others, 1981) and were supplemented by 37 new measurements (Andrew Griscom, unpub. data, 1984). The combined data were converted to Bouguer gravity values, and then an isostatic residual gravity map was constructed to isolate that part of the gravitational field that arises from near-surface density distributions (fig. 5). Sources of gravity anomalies were evaluated by comparing the gravity map with the distribution of major rock units.

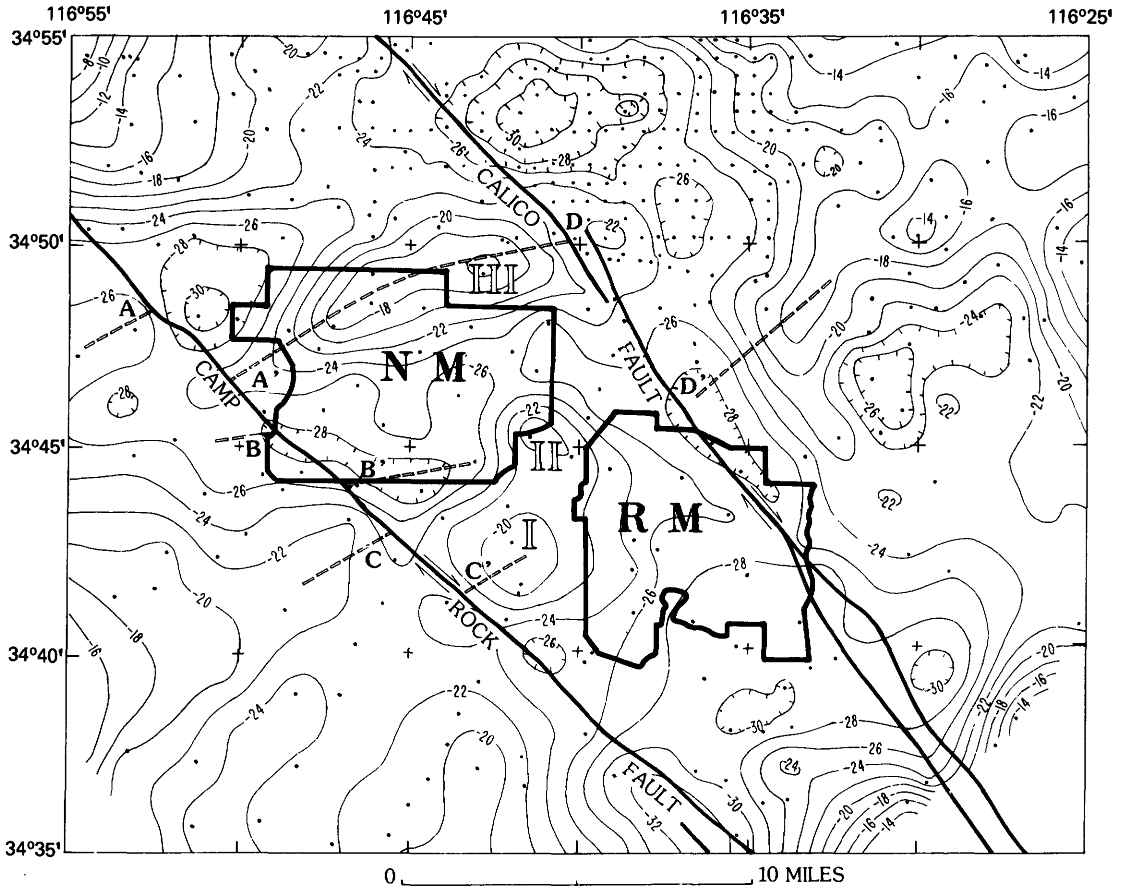
Local gravity highs of 5-8 milligals (mGals) amplitude are associated with dense Mesozoic metavolcanic rocks (fig. 5, anomalies I and II) and diorite (fig. 5, southwest part of anomaly III). The felsic Mesozoic granitic rocks, including the quartz monzonite, monzogranite, and syenogranite units, have a low average density of 2.63 g/cm^3 (14 samples) and produce gravity levels of about -22 to -28 mGals. The densities of the superimposed Miocene volcanic and sedimentary rocks must be lower than that of the granitic rocks by at least 0.2 and 0.3 g/cm^3, respectively. However, local gravity lows produced by the Miocene volcanic and sedimentary rocks amount to amplitudes of no more than -3 and -5 mGals, respectively, implying that the depth to pre-Cenozoic basement is everywhere less than 1,000 ft. Thus, the gravity data do not support major vertical offsets on normal faults bordering the tilted sections of Miocene rocks.

A gravity high (fig. 5, anomaly III) that extends northeastward across the northern boundary of the Newberry Mountains Wilderness Study Area is caused by a concealed body of relatively dense pre-Cenozoic rocks, probably either metavolcanic rocks or diorite. This gravity high is cut off to the northeast by the Calico fault at point D; a similar linear high at point D' (approximately 6 mi to the southeast along the fault) may be the offset extension of this gravity high. If so, this confirms the right-lateral strike-slip offset deduced for this fault from geology (Dokka, 1983, table 1). Similar analysis of offset gravity patterns on each side of the Camp Rock fault suggests right-lateral offset of about 2.5 mi, also in approximate agreement with the geologically deduced offset (Dokka, 1983, table 1).

Aeromagnetic Survey

Contoured aeromagnetic maps are available for all of the Newberry Mountains Wilderness Study Area and for about 20 percent of the Rodman Mountains Wilderness Study Area and extend to the southwest and northwest of both areas (U.S. Geological Survey, in press). The data were collected in 1957 and 1958 along parallel flight lines trending northeast and spaced 0.25 mi apart with a nominal altitude of 500 ft above ground. Contouring was done by hand and the Earth's main field was not removed. The main magnetic anomalies in and near the study areas are delineated on figure 6.

Comparison of the aeromagnetic map with the geologic map (fig. 2) indicates that large areas of Mesozoic metavolcanic rocks are moderately magnetic and produce anomalies of about 500 gammas (fig. 6, anomalies I and II), whereas the granitic rocks are at most weakly magnetic and rarely produce magnetic anomalies in excess of 100 gammas amplitude. In the Newberry Mountains Wilderness Study Area, Miocene intermediate and mafic volcanic rocks are relatively magnetic by comparison with interbedded sedimentary rocks and produce narrow linear magnetic highs, commonly less than 2,000 ft wide and 500 gammas in amplitude, that trend generally north or northwest parallel to the local structural trends in this region. These linear magnetic highs are terminated to the south by a steep south-sloping magnetic gradient (fig. 6, anomaly IV) that reflects a boundary with less magnetic strata of the upper unit of volcanic and sedimentary rocks, which consist of conglomerate and silicic tuff without any mafic or intermediate volcanic



EXPLANATION

Gravity contours--Hachured for closed lows; Roman numerals refer to gravity highs discussed in text; contour interval is 2 mGal

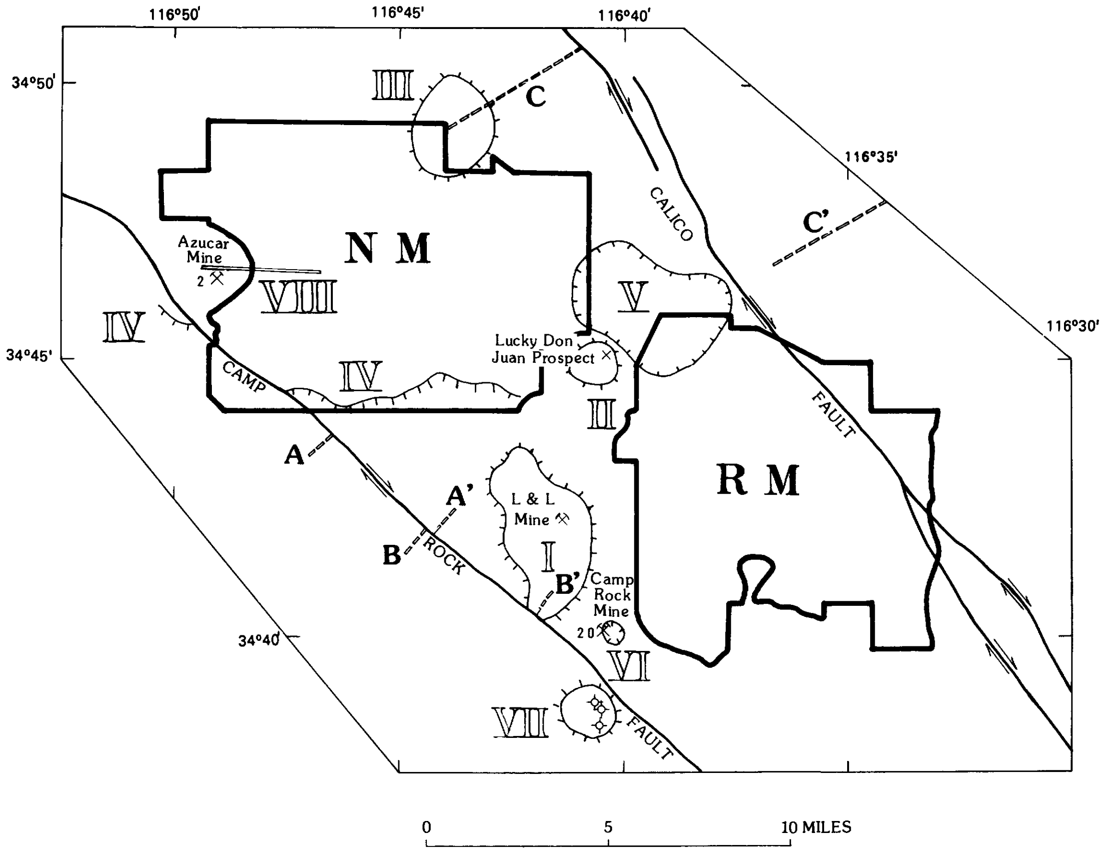
Fault--Arrows show direction of relative movement

Gravity-anomaly axis offset by fault; letters A, B, C, and D refer to axes that correspond to axes A', B', C', and D' on opposite side of fault

Boundary of Wilderness Study Area; NM is Newberry Mountains; RM is Rodman Mountains

• Gravity station

Figure 5. Isostatic residual gravity map of the Newberry Mountains and Rodman Mountains Wilderness Study Areas.



EXPLANATION

Boundary of magnetic high or low--Hachures point in direction of lower intensity of magnetic field; Roman numerals refer to anomalies discussed in text

Fault--Arrows show direction of relative movement

Discontinuity in magnetic contour pattern

Axis of magnetic anomaly offset by fault; letters A, B, and C refer to axes that correspond to axes A', B', and C' on opposite side of fault

Boundary of Wilderness Study Area; NM is Newberry Mountains; RM is Rodman Mountains

2 ⚒ × Mine or prospect; numbers refer to properties described in tables 1 and 2

⌖ Drill hole

Figure 6. Map showing aeromagnetic interpretation of the Newberry Mountains and Rodman Mountains Wilderness Study Areas.

rocks. This steep magnetic gradient trends approximately east along the north side of Kane Wash and appears to be truncated against the Camp Rock fault. The apparent westward extension of the magnetic gradient (fig. 6, anomaly IV') is offset about 2.4 mi northwestward along the Camp Rock fault, in close agreement with the right-lateral displacement of 2.5 mi inferred from the gravity map. In addition, the correlation of linear magnetic highs on each side of this fault (fig. 6: anomaly axes A and B correspond to axes A' and B', respectively) suggests right-lateral offsets of approximately 2.8 mi each.

Two major magnetic features on the map appear to have their source rocks concealed by a thin cover of Miocene sedimentary and volcanic rocks. The first feature, a magnetic high that overlaps the north border of the Newberry Mountains Wilderness Study Area, is about 300 gammas in amplitude and 2 mi in source width (fig. 6, anomaly III). This anomaly correlates with the eastern part of the gravity high (fig. 5, anomaly III) described previously and is tentatively interpreted as a concealed mass of Mesozoic metavolcanic rocks because this unit appears to be the only one that produces both gravity and magnetic highs. The second feature is a major magnetic low (fig. 6, anomaly V) about -700 gammas in amplitude and 2-3 mi wide. The west border of this feature is located within the Newberry Mountains Wilderness Study Area and its eastern part is located within the Rodman Mountains Wilderness Study Area. The approximate outline of the source mass is shown on figure 6. The anomaly is caused by a relatively thick mass of reversely magnetized rock buried no more than 1,000 ft below the surface. Because of its reverse magnetization, the source mass is interpreted to be a Tertiary stock or plug. Since there is no accompanying gravity anomaly, the intrusion apparently is composed of silicic or intermediate rock. Geometric relations between the magnetic low and an associated polarization high on its north side indicate that the intrusion has a vertical extent of at least 1.5 mi.

Several mines and prospects near the two study areas are associated with geophysical anomalies; therefore, similar geophysical anomalies might serve as guides to other mineral occurrences. The former L & L mine and the Lucky Don Juan prospect (fig. 6) are both near the crests of gravity and magnetic highs (anomalies I and II of figs. 5 and 6) associated with metavolcanic rocks. Accordingly, the gravity and magnetic highs (anomaly III of figs. 5 and 6) at the northern border of the Newberry Mountains Wilderness Study Area may be similarly associated with mineral occurrences concealed beneath the Miocene volcanic and sedimentary rocks. The gravity and magnetic data indicate that the Tertiary and Quaternary units within the Newberry and Rodman Mountains Wilderness Study Areas are relatively thin, overlying pre-Cenozoic basement rocks at depths of less than 1,000 ft. Thus, any concealed mineral deposits in the basement rocks should be at sufficiently shallow depths to be of economic interest. A small magnetic low (fig. 6, anomaly VI) that occurs over the Camp Rock mine may be caused by local hydrothermal alteration that destroyed magnetite. Similar magnetic features have not been identified within that part of the Rodman Mountains Wilderness Study Area covered by aeromagnetic data. A large magnetic high (fig. 6, anomaly VII) of 1,500 gammas amplitude is located over an alluviated valley at the southern border of the map area. This anomaly is associated with an outcrop of marble and a small body of magnetite-hematite scarn (Dibblee, 1964b). According to a U.S. Bureau of Land Management report (Vredenburgh, 1980), drilling near this magnetic high has delineated two large bodies of iron ore. No similar magnetic feature was identified within either study area. An east-trending discontinuity in the aeromagnetic contours that crosses the western border of the Newberry Mountains Wilderness Study Area (fig. 6, anomaly VIII) coincides with a zone of altered rocks, geochemical anomalies, and east-trending faults (zone A on fig. 2). The Azucar mine lies near the west end of this discontinuity.

Another feature of possible economic interest is the large reversed magnetic anomaly (fig. 6, anomaly V) that is interpreted to be a Tertiary intrusion. This intrusion, though concealed, could be a source of Tertiary epithermal mineralization.

Conclusions

General Summary

A review of regional mineral resource patterns indicates that the general vicinity of the Newberry and Rodman Mountains is characterized by three main types of mineral deposits. First, Tertiary rock sequences in the region locally contain epithermal vein and disseminated deposits of gold and silver, as exemplified by the Calico mining district northwest of the Newberry Mountains. These epithermal deposits typically contain only small amounts of copper and sulfide minerals and contain a high ratio of silver to gold. Second, the pre-Cenozoic rocks in ranges south and west of the Newberry and Rodman Mountains contain low-tonnage but locally rich vein deposits of gold, silver, and copper. Third, skarn deposits containing tungsten and iron minerals are present in several nearby ranges where plutonic rocks have intruded calcareous metasedimentary rocks.

Despite the existence of these mineral deposits in nearby areas, there are no known deposits of gold, silver, copper, iron, or tungsten in either wilderness study area. In this final section, the mineral resource potential of the study areas, that is, the likelihood that undiscovered mineral resources are present, is assessed by integrating the pertinent evidence from geologic, geochemical, and geophysical studies and the local prospecting history. Areas having mineral resource potential are shown on figure 2. Definitions of levels of mineral resource potential and certainty of assessment are provided in appendix 1.

Two areas in the Newberry Mountains Wilderness Study Area have moderate potential, certainty level B, for epithermal precious-metal deposits: an area at the east end of the study area has potential for silver, and an area at the west end of the study area has potential for both gold and silver. Two areas in the Rodman Mountains Wilderness Study Area contain vein occurrences of precious and base metals, and both of these areas are assigned a moderate mineral resource potential, certainty level C, for gold, silver, and copper. Gold-bearing terrace gravels that occur locally in the Rodman Mountains Wilderness Study Area are assigned a low potential, certainty level B, for placer gold resources.

Large mappable bodies of metasedimentary rocks were not observed in either study area, and skarn-related resources of iron or tungsten consequently are unlikely to be found in either area. Because the Miocene rock sequences in both areas lack fine-grained sedimentary rocks, sediment-hosted accumulations of boron, strontium, uranium, and bentonitic clay similar to those found in neighboring mountain ranges to the north and east are unlikely to be present in either study area. Leedom and Kiloh (1978) sampled Mesozoic plutonic rocks and Miocene volcanic and sedimentary rocks from the vicinity of the Newberry Mountains and Rodman Mountains Wilderness Study Areas and obtained uranium values that fall within normal background levels for the Mojave Desert region. No evidence of oil, gas, or geothermal energy resources was found in either wilderness study area.

Mineral Resource Potential of the Newberry Mountains Wilderness Study Area

An arcuate zone of altered, veined, and faulted rocks that crosses the west margin of the Newberry Mountains Wilderness Study Area (zone A on fig. 2) has a moderate resource potential, certainty level B, for epithermal deposits of gold and silver. This assessment is based on the following evidence: (1) geochemical anomalies in veins, altered rocks, and stream-sediment concentrates; (2) a local concentration of limonitic minerals astride the western border of the study area; (3) an aeromagnetic discontinuity that approximately coincides with zone A; and (4) minor recorded production of gold at the Azucar mine, which lies outside the study area near the west end of the zone. The supporting evidence is ambiguous, particularly regarding the eastern part of zone A, which lies within the study area. Several prominent anomalies for gold and silver were detected in heavy-mineral concentrates, but these anomalies may represent detrital material recycled from Miocene conglomerate, rather than epithermal mineralization within zone A. The gold-bearing quartz veins at the Azucar mine are located in plutonic rocks and may be Mesozoic in age. There is no direct evidence indicating that gold and silver have been introduced into the Miocene rocks that underlie the eastern part of zone A. Nevertheless, veins and altered volcanic rocks in the eastern part of the zone contain anomalous concentrations of arsenic and mercury, and this is a favorable indication that epithermal veins containing gold and silver could be present in the study area.

Zone B at the east end of the Newberry Mountains Wilderness Study Area has a moderate resource potential, certainty level B, for epithermal silver. Supporting evidence includes the following: (1) locally intense potassium metasomatism of Miocene volcanic rocks; (2) anomalous concentrations of barium, lead, and silver in stream-sediment concentrates and anomalous concentrations of arsenic and silver in veins and altered rocks; (3) abundant exposed Miocene intrusions; and (4) an aeromagnetic anomaly indicating a large concealed Tertiary intrusive body that could have supplied heat for prolonged hydrothermal circulation, rock alteration, and epithermal mineralization. However, direct evidence of mineralization in the form of veins or disseminated occurrences containing silver minerals have not been found in the Newberry Mountains either by this study or by historical prospecting. Furthermore, large veins of barite and jasper such as those that host silver deposits in the Calico Mountains have not been observed in the Newberry Mountains region. Therefore, if epithermal silver deposits are present in zone B, they probably are comparatively small, low-grade, or are concealed at depth.

There also is evidence for widespread low-grade epithermal mineralization throughout much of the northern half of the Newberry Mountains Wilderness Study Area. This evidence consists of numerous veins of manganese-oxide minerals and manganiferous black calcite, some containing low concentrations of silver, copper, lead, molybdenum, zinc, and tungsten. However, these veins invariably are too small to be considered manganese resources, and the metal concentrations are too low to indicate any resource potential for silver or other metals.

Mineral Resource Potential of the Rodman Mountains Wilderness Study Area

Zones C and D in the southwestern and northern parts of the Rodman Mountains Wilderness Study Area have a moderate resource potential, certainty level C, for gold, silver, and copper. These zones contain prospects that expose quartz and barite veins and altered rocks, all of which contain copper minerals and anomalous concentrations of silver and, in some places, gold (zone C, table 2, sites 17, 19, 20, and 21; zone D, table 2, site 14). Zone C straddles an area of albitized plutonic rocks that may represent deep-seated hydrothermal alteration contemporaneous with mineralization. Both zones contain areas with anomalous concentrations of limonitic minerals. Zone D is further delineated by anomalous concentrations of bismuth, copper, lead, and silver in stream-sediment concentrates collected within and downstream from the zone. However, the mineral occurrences in zones C and D are low grade and sparse, and no resources were identified. Stream-sediment geochemistry does not provide strong evidence of significant mineral concentrations in either zone. Any mineral resources that might exist within zones C and D probably would be limited to small deposits of gold, silver, and copper similar to those previously mined in the Fry and Ord Mountains areas to the south and west of the study area.

Zone E near the east margin of the study area has a low resource potential, certainty level B, for placer gold. A single panned sample of terrace alluvium (table 2, site 15) from the zone contained 0.0165 oz/yd^3 gold. The boundary of zone E is drawn to include both the sampled terrace deposit and neighboring terrace deposits of similar age. The anomalous concentration of gold in the reconnaissance sample may warrant additional geochemical studies of the terrace gravels in this area. However, the combined geologic and geochemical data for adjacent parts of the study area suggest that placer gold resources are unlikely to exist in zone E. The gold-bearing stream terrace overlies Miocene volcanic and sedimentary rocks, but the gold probably was derived from plutonic rocks upstream on the southwest side of the Calico fault system. The plutonic rocks apparently are only weakly mineralized and probably do not contain sufficient amounts of gold to generate placer gold resources downstream in zone E. The anomalous placer gold concentration measured in zone E may have come from quartz veins in zone D, where some evidence of mineralization has been observed. If so, then zone D probably was subsequently displaced at least 0.5 mi from the gold-bearing terrace gravels by right-lateral displacement on the Calico fault, probably during late Pleistocene and Holocene time.

There is no potential for radioactive-mineral resources in the Rodman Mountains Wilderness Study Area based on currently available information. An aerial gamma-ray spectroscopy survey (High Life Helicopters, Inc., 1980) indicates anomalous concentrations of thorium and slightly anomalous concentrations of uranium over the outcrop belt of quartz monzonite in the western part of the study area. These anomalies probably are attributable to the rare-earth phosphate mineral monazite, which was identified in the stream-sediment concentrates from this area. The monazite probably is disseminated in the quartz monzonite or within pegmatitic bodies within the quartz monzonite. In either case, it is unlikely to be concentrated enough to constitute a resource for thorium, uranium, or rare-earth elements.

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APPENDIX 1. Definition of levels of mineral resource potential and certainty of assessment

Mineral resource potential is defined as the likelihood of the presence of mineral resources in a defined area; it is not a measure of the amount of resources or their profitability.

Mineral resources are concentrations of naturally occurring solid, liquid, or gaseous materials in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.

Low mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment where the existence of resources is unlikely. This level of potential embraces areas of dispersed mineralized rock as well as areas having few or no indications of mineralization. Assignment of low potential requires specific positive knowledge; it is not used as a catchall for areas where adequate data are lacking.

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 a reasonable chance for resource accumulation, and where an application of genetic and (or) occurrence models indicates favorable ground.

High mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resources, where interpretations of data indicate a high likelihood for resource accumulation, where data support occurrence and (or) genetic models indicating presence of resources, and where evidence indicates that mineral concentration has taken place. Assignment of high resource potential requires positive knowledge that resource-forming processes have been active in at least part of the area; it does not require that occurrences or deposits be identified.

Unknown mineral resource potential is assigned to areas where the level of knowledge is so inadequate that classification of the area as high, moderate, or low would be misleading. The phrase "no mineral resource potential" applies only to a specific resource type in a well-defined area. This phrase is not used if there is the slightest possibility of resource occurrence; it is not appropriate as the summary rating for any area.

Expression of the certainty of the mineral resource assessment incorporates a consideration of (1) the adequacy of the geologic, geochemical, geophysical, and resource data base available at the time of the assessment, (2) the adequacy of the occurrence or the genetic model used as the basis for a specific evaluation, and (3) an evaluation of the likelihood that the expected mineral endowment of the area is, or could be, economically extractable.

Levels of certainty of assessment are denoted by letters, A-D (fig. 7).

A. The available data are not adequate to determine the level of mineral resource potential. Level A is used with an assignment of unknown mineral resource potential.

B. The available data are adequate to suggest the geologic environment and the level of mineral resource potential, but either evidence is insufficient to establish precisely the likelihood of resource occurrence, or occurrence and (or) genetic models are not known well enough for predictive resource assessment.

C. The available data give a good indication of the geologic environment and the level of mineral resource potential, but additional evidence is needed to establish precisely the likelihood of resource occurrence, the activity of resource-forming processes, or available occurrence and (or) genetic models are minimal for predictive applications.

D. The available data clearly define the geologic environment and the level of mineral resource potential, and indicate the activity of resource—forming processes. Key evidence to interpret the presence or absence of specified types of resources is available, and occurrence and (or) genetic models are adequate for predictive resource assessment.

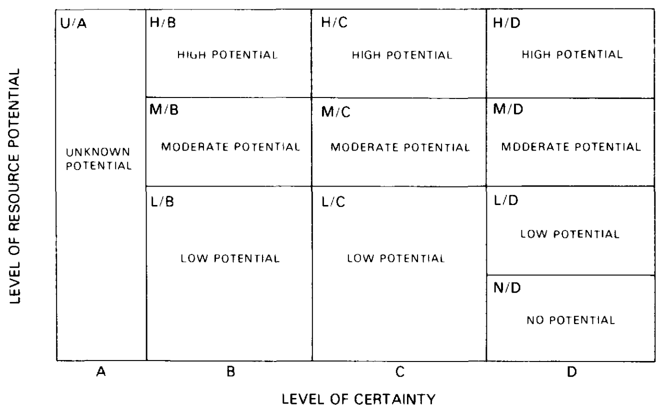

Figure 7. Major elements of mineral resource potential/certainty classification.

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 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	~570[1]
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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