Mineral Resources of the Morongo Wilderness Study Area, San Bernardino County, California

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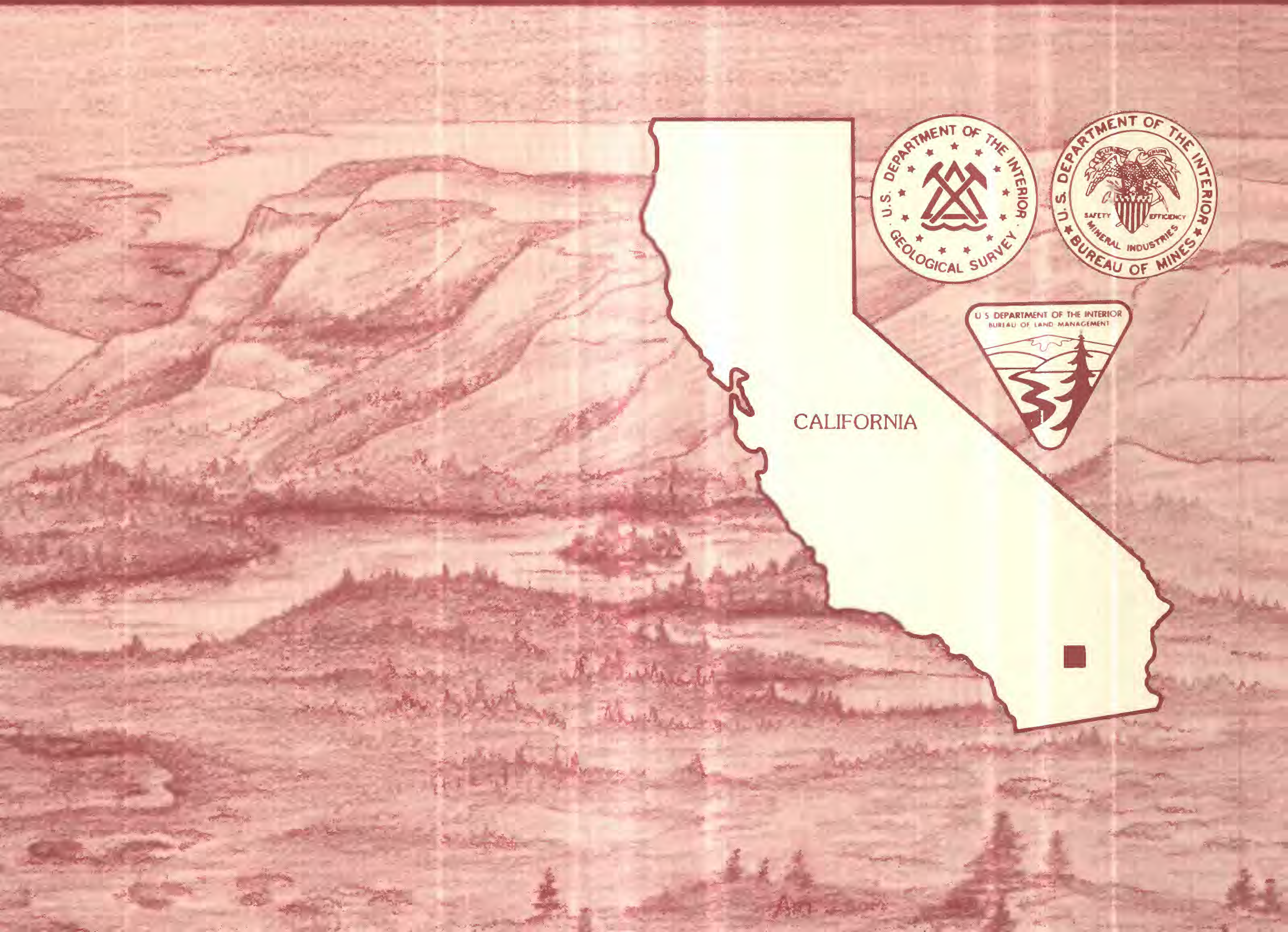

Chapter B

Mineral Resources of the Morongo Wilderness Study Area, San Bernardino County, California

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U.S. GEOLOGICAL SURVEY BULLETIN 1710

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

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of part of the Morongo Wilderness Study Area (CDCA-218), California Desert Conservation Area, San Bernardino County, California.

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Mineral Resources of the Morongo Wilderness Study Area, San Bernardino County, California

By Jonathan C. Matti, Scott E. Carson, James E. Kilburn, Andrew Griscom, *and* Douglas V. Prose
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SUMMARY

Abstract

At the request of the Bureau of Land Management, studies were conducted on 6,400 acres of the Morongo Wilderness Study Area (CDCA-218) in the southeastern San Bernardino Mountains of southern California. The U.S. Bureau of Mines and the U.S. Geological Survey conducted geological, geophysical, and geochemical surveys during 1983 and 1984 to assess the mineral resources (known) and mineral resource potential (undiscovered) of the study area. The study area has no identified resources, although a small body of marble in the western part of the study area is a possible source of lime for cement and crushed rock for construction materials. On the basis of current information, marble within the study area does not constitute an identified resource. In the northern and eastern part of the study area, a unit of undifferentiated plutonic rocks has moderate potential for silver, lead, tin, and tungsten resources in scattered small-scale quartz veins. The remainder of the area studied has low potential for silver, lead, tin, and tungsten resources. The entire study area has low potential for thorium, rare-earth elements, uranium, geothermal, oil and gas, sand and gravel, and marble resources.

Character and Setting

The part of the Morongo Wilderness Study Area studied comprises 6,400 acres about 20 mi north of Desert Hot Springs and 30 mi west of Twentynine Palms, Calif. (fig. 1). The area is characterized by mountainous terrain that is underlain mainly by crystalline rocks, including undeformed plutonic igneous rocks of granitic composition that have intruded older igneous rocks. Sedimentary rocks in the study area were deformed and metamorphosed into granitic gneiss, marble, and metaquartzite. Stream canyons contain thin deposits of sand and gravel. There are no active mines, prospects, leases, or mining claims in the study area.

Mineral Resources and Mineral Resource Potential

Our investigations of historic mining and prospecting activity indicate that no mineral production has come from the wilderness study area. A small body of marble in the western part of the study area is a possible source for building stone and crushed and quarried aggregate for construction applications; the marble also could be a source of lime and magnesium for Portland cement and industrial applications, however, the marble does not currently constitute an identified resource. Sand and gravel in the study area are suitable for construction uses, but are of very limited extent. Similar, larger deposits outside the study area are closer to markets. There is low potential for sand, gravel, and marble resources within the study area.

Geologic and geochemical studies indicate that a unit of undifferentiated plutonic rocks in the northeastern part of the area has moderate potential for silver, lead, tin, and tungsten resources (fig. 2). Minor geochemical anomalies for these and associated metallic elements in hydrothermal-vein settings were detected in panned-concentrate samples of alluvium from three drainages that dissect the undifferentiated plutonic rock unit. Heavy-mineral suites from the samples included ore and ore-related minerals similar to those reported at the Pierce Ranch prospect, such

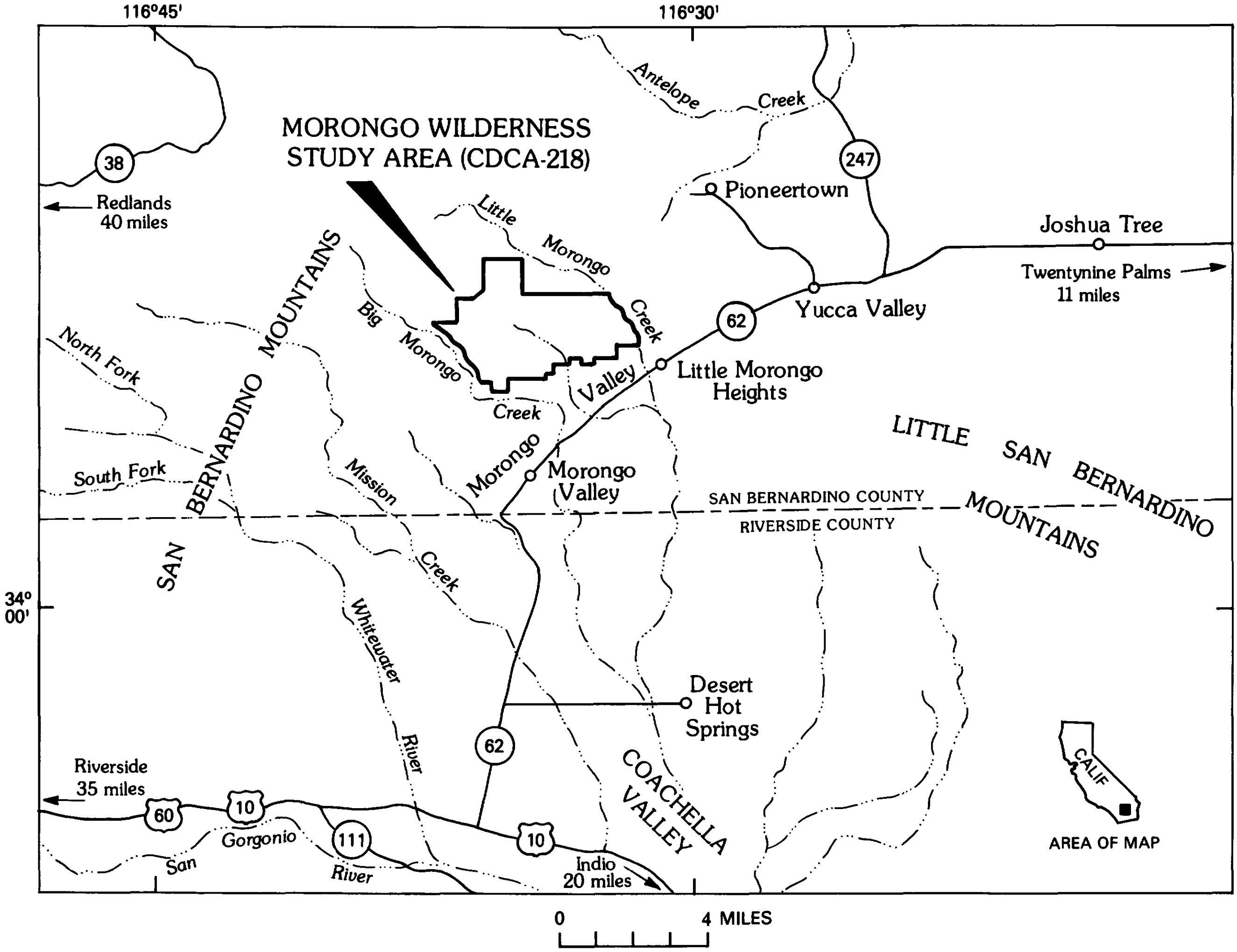

Figure 1. Index map showing location of the Morongo Wilderness Study Area, San Bernardino County, California.

as hematite, limonite, and minor chalcopyrite and azurite (Marcus, 1982). The rest of the Morongo Wilderness Study Area has low potential for silver, lead, tin, and tungsten resources. Geologic, geochemical, and geophysical investigations indicate that there is low potential for uranium, thorium, rare-earth elements, geothermal, and oil and gas resources within the study area.

INTRODUCTION

This mineral resource study is a joint effort by the U.S. Geological Survey and the U.S. Bureau of Mines. The history and philosophy of such joint mineral surveys of U.S. Bureau of Land Management Wilderness Study Areas were discussed by Beikman and others (1983). Mineral assessment methodology and terminology were discussed by Goudarzi (1984). Identified resources are classified according to the system described by U.S. Bureau of Mines and U.S. Geological Survey (1980). See appendix for the definition of levels of mineral resource potential, certainty of assessment, and classification of identified resources. Studies by the U.S. Geological Survey are designed to provide a reasonable scientific basis for assessing the potential for undiscovered mineral resources by determining geologic units and structures, possible environments of mineral deposition, presence of geochemical and geophysical anomalies, and applicable ore-deposit models. The U.S. Bureau of Mines evaluates identified resources at individual mines and known mineralized areas by collecting data on current and past mining activities and through field examination of mines, prospects, claims, and mineralized areas.

The part of the Morongo Wilderness Study Area (CDCA-218) studied encompasses about 6,400 acres in the southeastern part of the San Bernardino Mountains, about 20 mi north of Palm Springs and about 30 mi west of Twentynine Palms, Calif. The study area flanks the north margin of Morongo Valley, an alluviated valley situated between the San Bernardino and Little San Bernardino Mountains. The study area consists of rugged mountainous terrain that supports a flora of desert scrub and pinyon-juniper woodland.

Topographic relief ranges from about 3,000 ft to 6,305 ft. Watercourses form steep-sided canyons, and consist of ephemeral streams that drain southeast into Morongo Valley; two of these, Big and Little Morongo Creeks, occupy major canyons that form the west and east boundaries of the study area. The study area is accessible by numerous unpaved roads that lead north from California Highway 62.

The U.S. Bureau of Mines researched the history of prospecting, mineral claims, mining, and production within and near the study area, and assessed the identified mineral resources where possible. This study involved a literature search, field examination of workings and mineralized areas, and laboratory analysis of samples collected in the field (Kuizon, 1984). Reports containing information on mining and production within and near the area include those by DeGroot (1888), Hill (1912), Cloudman and others (1919), Wright and others (1953), Oesterling and Spurck (1964), Dibblee (1967), and Proctor (1968).

The U.S. Geological Survey assessed the mineral resource potential of the study area by integrating and interpreting geologic, geochemical, and geophysical data from existing sources and from new investigations. Field mapping conducted in 1984 provided most of the geologic information, and regional mapping by Dibblee (1967) provided supplementary geologic data. A reconnaissance stream-sediment sampling survey conducted in 1984 provided geochemical data (Detra and Kilburn, 1985). Existing aeromagnetic data (U.S. Geological Survey, 1979, 1982) provided a basis for geophysical interpretations. Aerial gamma-ray investigations (U.S. Department of Energy, 1980) conducted under the National Uranium Resource Evaluation (NURE) program provided the basis for evaluating the uranium resource potential of the area. Our evaluation of mineral resources within the study area benefitted from resource evaluations of nearby public lands: Cox and others (1983); Matti and others (1983); Powell and others (1983); and Matti and others (1982).

APPRAISAL OF IDENTIFIED RESOURCES

By Lucia Kuizon
U.S. Bureau of Mines

Methods and Scope of Investigation

Studies of the U.S. Bureau of Mines of the Morongo Wilderness Study Area entailed literature searches and review of mining-claim records. Field studies were conducted in 1983 and included examination of mines, claims, and prospects, and mapping and sampling of mineralized properties. Six rock samples and three alluvial samples were collected in and near the study area and checked for fluorescence and radioactivity. The rock samples were fire assayed for gold and silver content and analyzed by semiquantitative spectrography for 40 elements. The three alluvial samples were concentrated and checked microscopically for gold and other heavy minerals. Complete analytical data are included in Kuizon (1984).

Mining Activity

In 1983, there were no mining claims, prospects, or any other evidence of mining activity within the study area. Eight prospects and one patented group of mining claims and millsites are within 3 mi of the study area. The Pierce Ranch prospect (fig. 2) is about 0.5 mi northeast of the study area. A hematite and limonite vein containing gold, silver, and copper is exposed in a 100-ft adit (Oesterling and Spurck, 1964).

Mining activity near the study area in 1983 consisted of a sand and gravel operation in Yucca Valley 6 mi to the east and quarrying of limestone for cement in the Cushenberry quarry 20 mi to the northwest. The Morongo mining district lies north of the study area and may extend into it (Hill, 1912). Other mining districts nearby include the Black Hawk, Holcomb, Bear Valley, Ruby, and Twentynine Palms (DeGroot, 1888). Prospecting began in the San Bernardino Mountains in 1859, and gold placers were mined in 1860 in Bear and Holcomb Valleys, 20 mi northwest of the study area (Cloudman and others, 1919).

Mineral Occurrences

A small body of marble in the western part of the study area was mapped by the USGS during this study (Matti and others, this report, fig. 2). Other similar marble deposits in the San Bernardino Mountains are sources of (1) lime for cement and chemicals, (2) crushed aggregate for roofing granules, road bases, and decorative stone, (3) rip rap and building stone for construction purposes, and (4) calcium and magnesium carbonate for industrial and manufacturing applications (Gray, 1982; Joseph, 1982; Miller and Morton, 1982; Brown, 1982; and Fife and Brown, 1982). The quality and quantity of the carbonate rock present in the marble body in the study area was not assessed. However, because of the small surface outcrop, limited accessibility, and availability of large marble bodies elsewhere in the San Bernardino Mountains area that are more likely to be developed, the marble body is considered an occurrence.

Deposits of sand and gravel in the study area may provide possible sources of aggregate for construction uses. Larger gravel in creek bottoms may be a possible source for rip rap. However, stream deposits in the study area are thin and limited in areal extent. Larger, more easily accessible deposits are present in Morongo and Coachella Valleys (fig. 1), and some are being mined. Therefore, stream deposits within the study area are considered occurrences, not resources.

Granitic rocks in the study area may provide possible sources of crushed stone, decomposed aggregate, and rip rap. However, granitic rocks of equal quality and better accessibility are widespread in the San Bernardino Mountains area. Therefore, granitic rocks in the study area are occurrences, not resources.

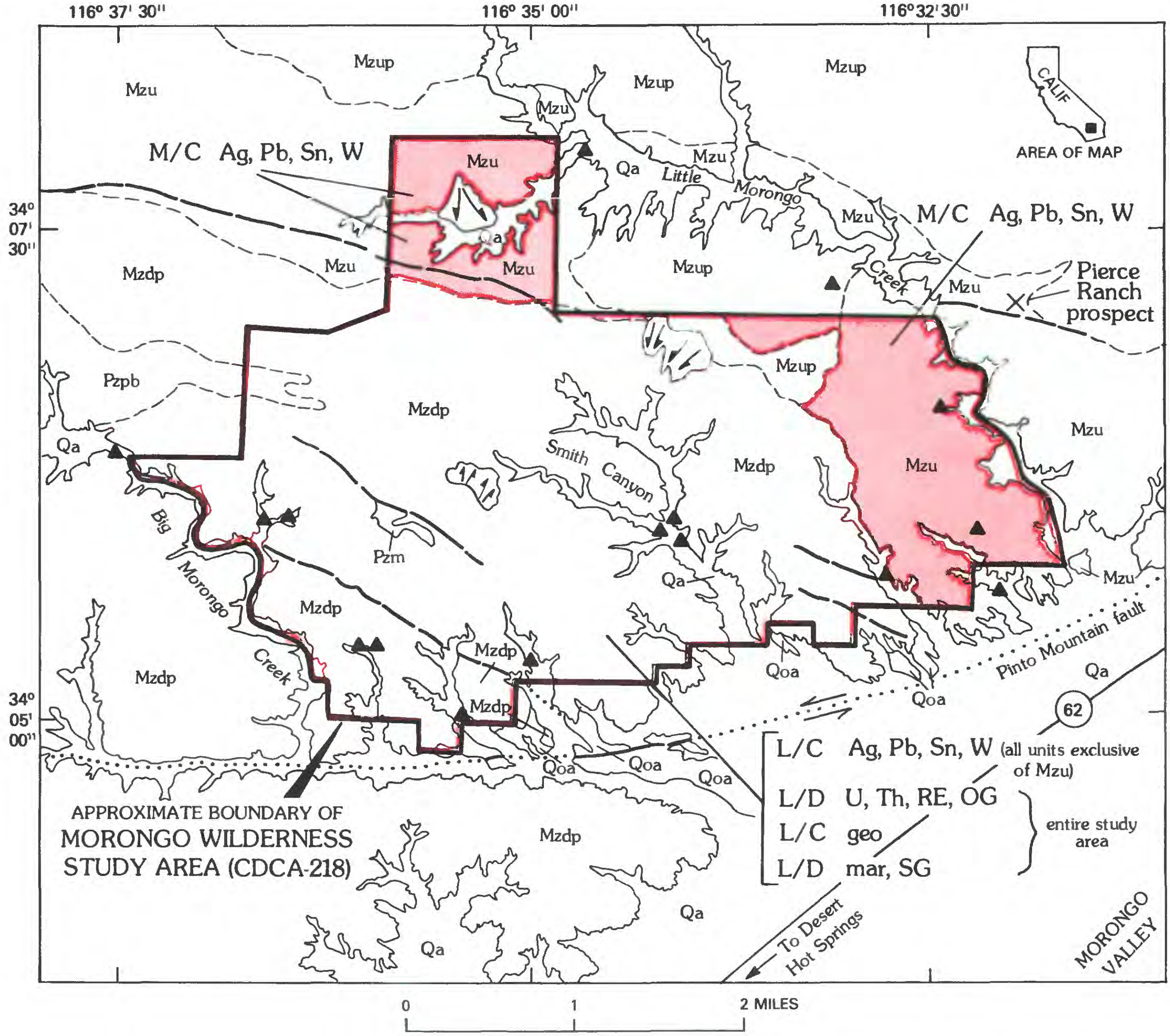

Figure 2. Mineral resource potential and generalized geology of the Morongo Wilderness Study Area, San Bernardino County, California.

Sampling Results

One alluvial sample from three placer claims immediately west of the study area along Big Morongo Creek (fig. 2) contained 2.0 mg/yd^3 (milligrams per cubic yard) flour gold. Two other alluvial samples taken from intermittent streams within the study area contained 2.25 mg/yd^3 and 6.5 mg/yd^3 of gold. Six rock samples were taken from altered rock outcrops within the study area. Two samples of iron-oxide-stained granitic rock from the southwestern and eastern parts of the study area contained 0.4 and 0.8 oz/ton silver. No other significant mineral values were found in the study area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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Geology

The Morongo Wilderness Study Area is underlain mainly by crystalline rocks that form three distinct suites: (1) an older suite of prebatholithic sedimentary rocks that were metamorphosed to marble and metaquartzite; (2) a suite of granitoid rocks that

EXPLANATION

	Area with moderate mineral resource potential
	Area with low mineral resource potential

See appendix for definition of levels of mineral resource potential and certainty of assessment

Commodities

Ag	Silver
Pb	Lead
Sn	Tin
W	Tungsten
U	Uranium
Th	Thorium
RE	Rare-earths
OG	Oil and gas
SG	Sand and gravel
geo	Geothermal
mar	Marble

Geologic map units

Qa	Alluvium (Quaternary)
Qoa	Older alluvium (Quaternary)
Mzup	Monzogranite and granodiorite of undeformed plutonic suite (Mesozoic)
Mzu	Undifferentiated unit of deformed and undeformed plutonic suite (Mesozoic)
Mzdp	Granitic gneiss of deformed plutonic suite (Mesozoic)
Pzm	Marble (Paleozoic)
Pzpb	Prebatholithic metasedimentary rocks (Paleozoic)

Contact—Dashed where approximately located

Fault—Dashed where approximately located; dotted where concealed. Arrows show direction of relative movement

Landslide deposit—Arrows show direction of movement

▲ Geochemical sample site

Figure 2. Continued.

intruded the prebatholithic suite and subsequently was deformed into well-foliated and layered granitic gneiss; and (3) a suite of undeformed plutonic rocks of granitic composition that intruded the two older suites in late Mesozoic time (see appendix for geologic time chart). These rocks are dissected by stream canyons that contain alluvial sand and gravel. The study area is cut by several northwest-trending, high-angle faults. The Pinto Mountain fault, a major left-lateral strike-slip fault that had more than 9 mi of displacement during late Cenozoic time (Dibblee, 1968), is present just south of the study area.

The prebatholithic rocks in the western part of the study area consist of a small body of marble and associated layers of metaquartzite. These rocks represent ancient accumulations of calcareous sediment and quartz-rich sand that originally were deposited in the sea, probably during late Precambrian or early Paleozoic time. During Mesozoic time the lithified sediments were intruded by large granitic magma bodies that metamorphosed the sedimentary rock to metaquartzite and marble. Within the study area, the granitic intrusions engulfed and assimilated most of the sedimentary rocks; however, a few miles to the west, the sedimentary rocks escaped total assimilation and formed extensive outcrops of metaquartzite and subordinate marble (Dibblee, 1967). Prebatholithic metasedimentary rocks in the study area represent discontinuous extensions of the adjacent metasedimentary belt.

The deformed plutonic suite (terminology of Matti and others, 1982) in the study area is an assemblage of granitic gneiss and foliated granitoid rock. It consists of light- to dark-colored granitic gneiss that is well foliated or that has compositionally layered fabrics in which the layering is well defined to streaky and diffuse. The gneiss is predominantly granodioritic in composition, but includes rock that is tonalitic. Textural features indicate a plutonic origin for the gneisses, although their original plutonic aspect has been obscured by subsequent deformation that created the foliated and layered fabrics. Dibblee (1967) concluded that the granitic gneiss in the study area and vicinity is older than the prebatholithic metasedimentary rocks, and he tentatively inferred a Precambrian age for the gneiss. We conclude that the granitic gneiss intruded the metasedimentary rocks and is early Mesozoic(?) in age (Matti and others, 1982).

Texturally massive to slightly foliated late Mesozoic plutonic rocks comprise the undeformed plutonic suite (terminology of Matti and others, 1982) in the study area. This suite consists of light-colored, biotite-bearing monzogranite and granodiorite that locally contain muscovite and garnet. All units of the undeformed plutonic suite intrude granitic gneiss of the deformed plutonic suite. In the eastern part of the study area, the two suites are mixed together so intimately that we mapped them together as undifferentiated plutonic rocks. Quartz veins and siliceous dikes cut these granitic rocks.

Two types of alluvial sand and gravel are present in the study area: relatively undissected alluvium that accumulated during late Quaternary time and older dissected alluvium that accumulated in earlier Quaternary time. Both of these types were deposited by streams and floods.

Geochemical Studies

A reconnaissance geochemical survey of alluvial sediment in the Morongo Wilderness Study Area was conducted for 30 elements. Detra and Kilburn (1985) describe sample collection and processing procedures. Nonmagnetic heavy- mineral panned concentrates from the sediments were analyzed by a six-step semiquantitative emission-spectrographic method described by Grimes and Marranzino (1968).

Three panned-concentrate samples from the northeastern part of the study area contain metallic sulfides that indicate a metallic-element suite that includes silver, lead, tin, bismuth, and tungsten. Several concentrates from the southwestern part of the study area contain barite and scheelite and have anomalous concentrations of barium and tungsten, and one sample contained pyrite. These occurrences probably are similar to a mineralized quartz vein at the Pierce Ranch prospect (fig. 2) described by Oesterling and Spurck (1964), who reported assay values of 5.4 oz silver, 0.08 oz gold, 1.3 percent copper, and the ore-related minerals hematite, limonite, and minor chalcopyrite and azurite (cited in Marcus, 1982).

The silver-lead-bismuth association is typical of hydrothermal veins, and tungsten can be present in veins even though it typically is a skarn mineral. Except for tungsten, the metallic association may result partly from contamination by lead shot. Analysis of shot removed from one of the concentrates revealed an elemental suite (silver, bismuth, cadmium, copper, lead, and antimony) that is also commonly associated with hydrothermal mineralization (Detra and Kilburn, 1985).

Barium and tungsten from several samples in the southwestern part of the study area may have two possible sources: (1) scheelite in skarns associated with the small body of marble and stringers of metaquartzite that are intruded by granitic gneiss of the deformed plutonic suite; and (2) scheelite-bearing quartz-barite hydrothermal veins within the deformed plutonic suite.

Anomalous concentrations of titanium and zirconium are present in virtually all of the sediment samples. We attribute these to abundant sphene, rutile, and zircon present in all of the samples; these minerals are common accessory minerals in granitic rocks. Similarly, locally elevated values for lanthanum probably represent lanthanum substituting for calcium in sphene. Reconnaissance geochemical studies conducted in the Morongo and adjacent Bighorn Mountains Wilderness Study Areas (Matti and others, 1982) suggest that the eastern San Bernardino Mountains may have high background levels for titanium, zirconium, and rare-earth elements and transition metals.

Geophysical Studies

The Morongo Wilderness Study Area is covered by two aeromagnetic maps (U.S. Geological Survey, 1979, 1982). The aeromagnetic data were collected along parallel north-trending flightlines spaced 0.5 mi apart with a nominal altitude of 1,000 ft above ground.

In general, variations in the Earth's magnetic field as depicted on a residual map are caused by variations in the amounts of magnetic minerals of different rock units, magnetite being the common magnetic mineral in this area. Magnetic minerals, where locally either concentrated or absent, may cause magnetic anomalies that can be guides to mineral occurrences or deposits.

The granitic gneiss in the southwestern part of the study area is relatively magnetic; the local topographic highs there produce magnetic anomalies as high as 400 gammas in amplitude. Granitic rocks in the northern part of the study area are only weakly magnetic; the topographic highs produce a few magnetic highs with values of less than about 50 gammas. A steep magnetic gradient sloping down to the northeast and trending northwest across the center of the study area (U.S. Geological Survey, 1979) is the magnetic expression of a boundary between magnetic gneiss to the southwest and weakly magnetic granitic rocks to the northeast.

Geophysical investigations 15 mi to the north in the Bighorn Mountains Wilderness Study Area (Matti and others, 1982) indicate that some magnetic highs are associated with mineralized zones and that magnetic lows are associated with metallic prospects and altered zones where hydrothermal rock alteration has apparently destroyed the magnetite. No magnetic lows of this sort are identified in the Morongo Wilderness Study Area. The major isolated magnetic high in the northeastern part of the study area is most likely caused by granitic gneiss in the undifferentiated plutonic rocks unit, although occurrences of hornblende diorite mapped by Dibblee (1967) in this vicinity also could account for this isolated high.

Gravity data for the study area (Oliver and others, 1980; Roberts and others, 1981) are too sparse to permit making any local interpretations. An airborne gamma-ray spectrometer survey is available for the San Bernardino Mountains (U.S. Department of Energy, 1980) and includes one helicopter traverse at a flight altitude of 400 ft eastward across the study area at approximately lat 34°06' N. No uranium or thorium anomalies, which may indicate possible uranium resources, were recognized within the study area in the results of the aeroradiometric survey.

Mineral Resources

Geochemical anomalies for silver, lead, tin, and tungsten were detected in three alluvial samples from separate tributaries of Little Morongo Creek, in the northeastern part of the study area. The origin of the metallic anomalies is unknown, and they in part may reflect contamination by lead shot, which yields a similar geochemical signature. However, three factors suggest a high likelihood that mineralization has occurred: (1) mineralized quartz veins containing gold, silver, and copper are present in the same geologic setting just outside the study area at the Pierce Ranch prospect, (2) galena, cerussite, and pyrite are present in one of the samples and scheelite is in all three, and (3) a bedrock sample collected from the undifferentiated plutonic rock unit that is drained by the three tributaries contained silver. Thus, we have assigned moderate mineral resource potential, certainty level C, for silver, lead, tin, and tungsten in the undifferentiated plutonic rocks unit. However, there is no indication that undiscovered occurrences are larger in scale than those at the Pierce Ranch prospect, a deposit that has no known reserves, no production, and resources that presumably are subeconomic (resource terminology from U.S. Bureau of Mines and U.S. Geological Survey, 1980).

Elsewhere in the study area, generalized geologic environments exist that may include potential sites for localized deposits of silver and associated precious- and base-metals. Thus, we assign low potential, certainty level C, for silver, lead, tin, and tungsten resources in the part of the study area not underlain by the unit of undifferentiated plutonic rocks.

Geophysical and geochemical studies indicate that the wilderness study area has low potential, certainty level D, for uranium, thorium, and rare-earth element resources. An airborne gamma-ray spectrometer study of the region (U.S. Department of Energy, 1980) showed that uranium and thorium levels in the wilderness study area are low by comparison with locally elevated gamma-ray signals for these elements elsewhere in the eastern San Bernardino Mountains. Our geochemical survey showed that values for thorium and for rare-earth element and transition metals like lanthanum, yttrium, and niobium are within background levels for the study area.

Although the study area is adjacent to a region of known geothermal resources near Desert Hot Springs, no hot springs or hot-water wells were identified. Thus, the study area has low potential for geothermal resources, with a certainty level of C.

The Morongo Wilderness Study Area has low potential for oil and gas resources, with a certainty of D. Scott (1983) states that the region including this area is not likely to have any potential for oil and gas. However, no known exploration has been conducted in or near the Morongo Wilderness Study Area, and there is a slight possibility that faulting adjacent to the study area could have produced pockets that contain oil or gas. There are no known source rocks in or near the study area.

A small body of marble in the western part of the study area and accumulations of sand and gravel that are present in narrow stream valleys that drain the study area could be used for industrial purposes. The resource content of the marble occurrence was not identified. Additional marble occurrences are not likely in the study area; our mapping has shown the predominant rock type to consist mainly of granite and gneiss. Therefore, the potential for marble resources is low, with a certainty level of D. No other occurrences of sand and gravel are present in the study area beyond those indicated in figure 2. Within the study area, the potential for sand and gravel resources is low, with a certainty level of D.

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

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

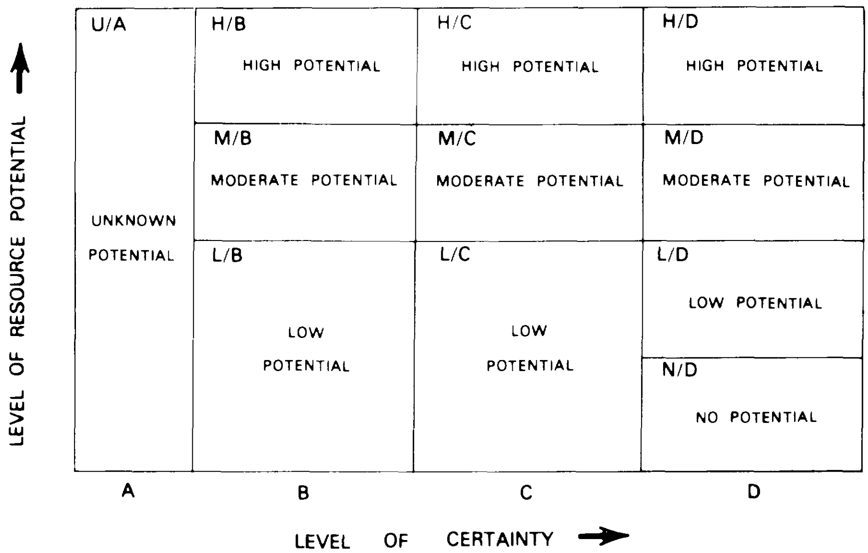
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate reasonable likelihood of resource accumulation, and (or) where an application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

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

UNKNOWN mineral resource potential is assigned to areas where information is inadequate to assign low, moderate, or high levels of resource potential.

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

Levels of Certainty



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

Abstracted with minor modifications from:

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

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RESOURCE/RESERVE CLASSIFICATION

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

Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, p. 5.

GEOLOGIC TIME CHART

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

EON	ERA	PERIOD		EPOCH	AGE ESTIMATES OF BOUNDARIES (in 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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March 3, 1849