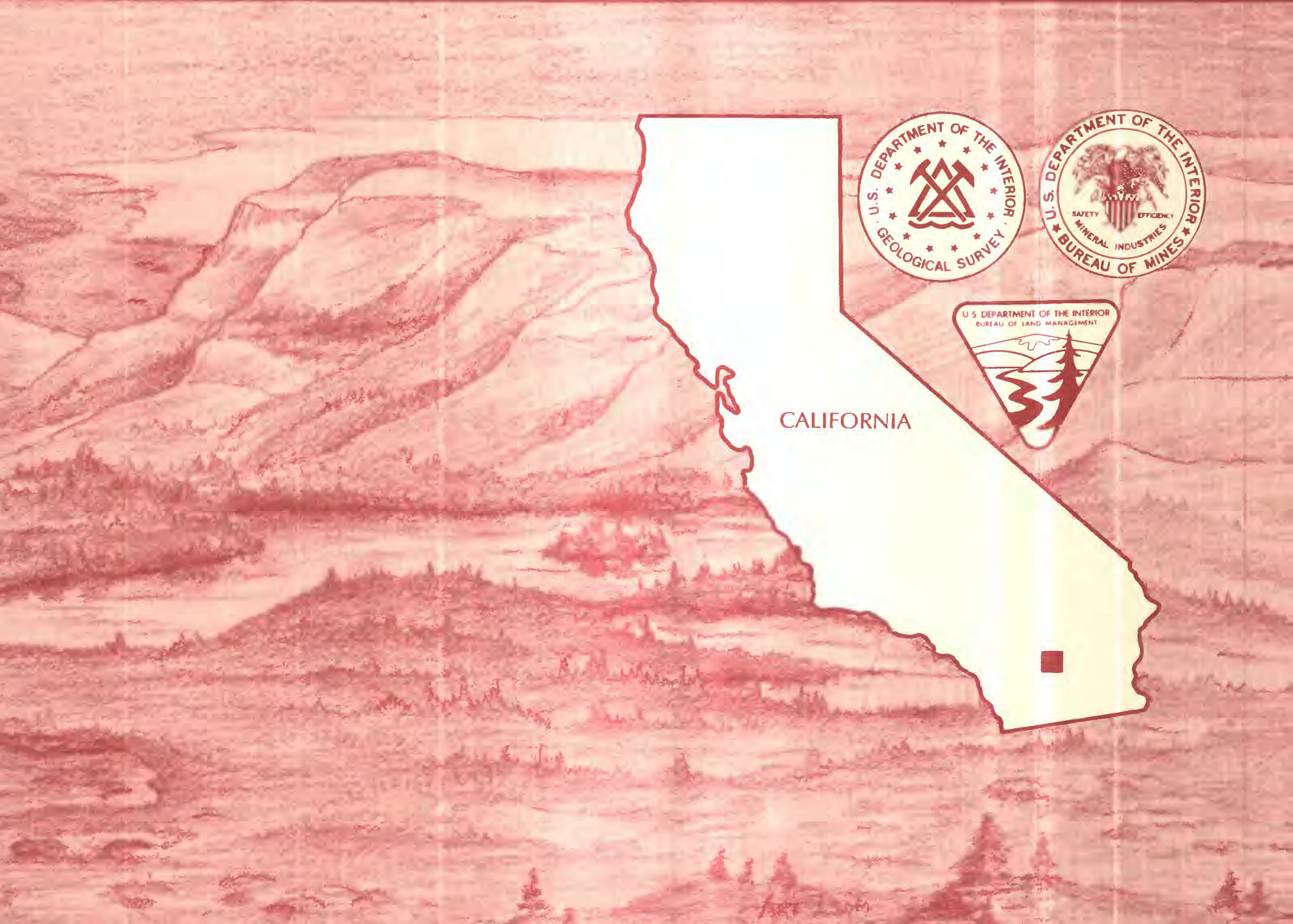
Mineral Resources of the Santa Rosa Mountains Wilderness Study Area, Riverside County, California

U.S. GEOLOGICAL SURVEY BULLETIN 1710-D



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Chapter D

Mineral Resources of the Santa Rosa Mountains Wilderness Study Area, Riverside County, California

By J.P. CALZIA, D.J. MADDEN-McGUIRE, and H.W. OLIVER
U.S. Geological Survey

R.A. SCHREINER
U.S. Bureau of Mines

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
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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Area

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 the Santa Rosa Mountains Wilderness Study Area (CDCA-341), California Desert Conservation Area, Riverside County, California.

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Mineral Resources of the Santa Rosa Mountains Wilderness Study Area, Riverside County, California

By J.P. Calzia, D.J. Madden-McGuire, *and* H.W. Oliver
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SUMMARY

Abstract

The Santa Rosa Mountains Wilderness Study Area (CDCA–341) covers 68,051 acres in the Santa Rosa Mountains, California. An appraisal of the mineral resources (known) and an assessment of mineral resource potential (undiscovered) of this wilderness study area, hereinafter designated "the study area," were made at the request of the U.S. Bureau of Land Management and are described in this report. There are no identified mineral resources in the study area. Geologic, geochemical, geophysical, and mineral surveys indicate that the study area has high potential for tungsten and marble resources, moderate potential for gold, and no potential for oil, natural gas, and geothermal resources.

Character and Setting

The Santa Rosa Mountains Wilderness Study Area is in mountainous terrain 15 mi south-southeast of Palm Springs, Calif. (fig. 1). Access to and within the study area is limited to unmaintained jeep trails and existing foot trails. Topographic relief, expressed by steep ridges and deep steep-walled canyons, is about 6,200 ft.

The geologic setting of the study area is unusual in that it sits astride a zone of sheared, pulverized rock known as the Santa Rosa mylonite zone. This mylonite zone was caused by a block of rocks being thrust southwest at about the same time as intrusive rocks pushed upward to form the Peninsular Ranges batholith. Rocks structurally below the mylonite zone, in the lower plate, include gneiss, schist, marble, and metasedimentary rocks intruded by quartz monzonite, gabbro, and tonalite of the batholith. The Santa Rosa mylonite zone includes crushed and deformed gneiss, marble, and tonalite. Rocks structurally above the Santa Rosa mylonite zone, in the upper plate, include marble, gneiss, schist, metasedimentary rocks, and granitic rocks. These upper-plate rocks were thrust westward over the mylonite zone along a series of low-angle thrust faults that are spatially and temporally related to the Santa Rosa mylonite zone.

Mineral Resources and Mineral Resource Potential

Twelve mines, prospects, and mineral occurrences are present in or adjacent to the study area, however there are no identified resources present. Gneiss and schist in the lower plate have high potential for tungsten resources in skarns. Both upper and lower plates have high resource potential for marble that may be used in the manufacture of Portland cement and for construction materials. Quartz veins that cut quartz monzonite, gneiss, and schist in the lower plate and mylonitic rocks in the upper plate have moderate potential for gold resources. Oil, natural gas, and geothermal resources are not present and there is no potential for resources of them within the study area.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management and is a joint effort by the U.S. Geological Survey and the U.S. Bureau of Mines. An introduction to the wilderness review process, mineral

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survey methods, and agency responsibilities were provided by Beikman and others (1983). The U.S. Bureau of Mines evaluates identified resources at individual mines and known mineralized areas by collecting data on current and past mining activities and through field examination of mines, prospects, claims, and mineralized areas. Identified resources are classified according to a system that is a modification of that described by McKelvey (1972) and U.S. Bureau of Mines and U.S. Geological Survey (1980). 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. Mineral assessment methodology and terminology as they apply to these surveys were discussed by Goudarzi (1984). See the appendixes for definition of levels of mineral resource potential, certainty of assessment, and classification of identified resources.

Location and Physiography

The Santa Rosa Mountains Wilderness Study Area (CDCA-341) covers 68,051 acres in the Santa Rosa Mountains about 15 mi south-southeast of Palm Springs, Calif. (fig. 1). The study area is accessible by foot trails from Toro Peak and by unmaintained jeep trails from Coachella

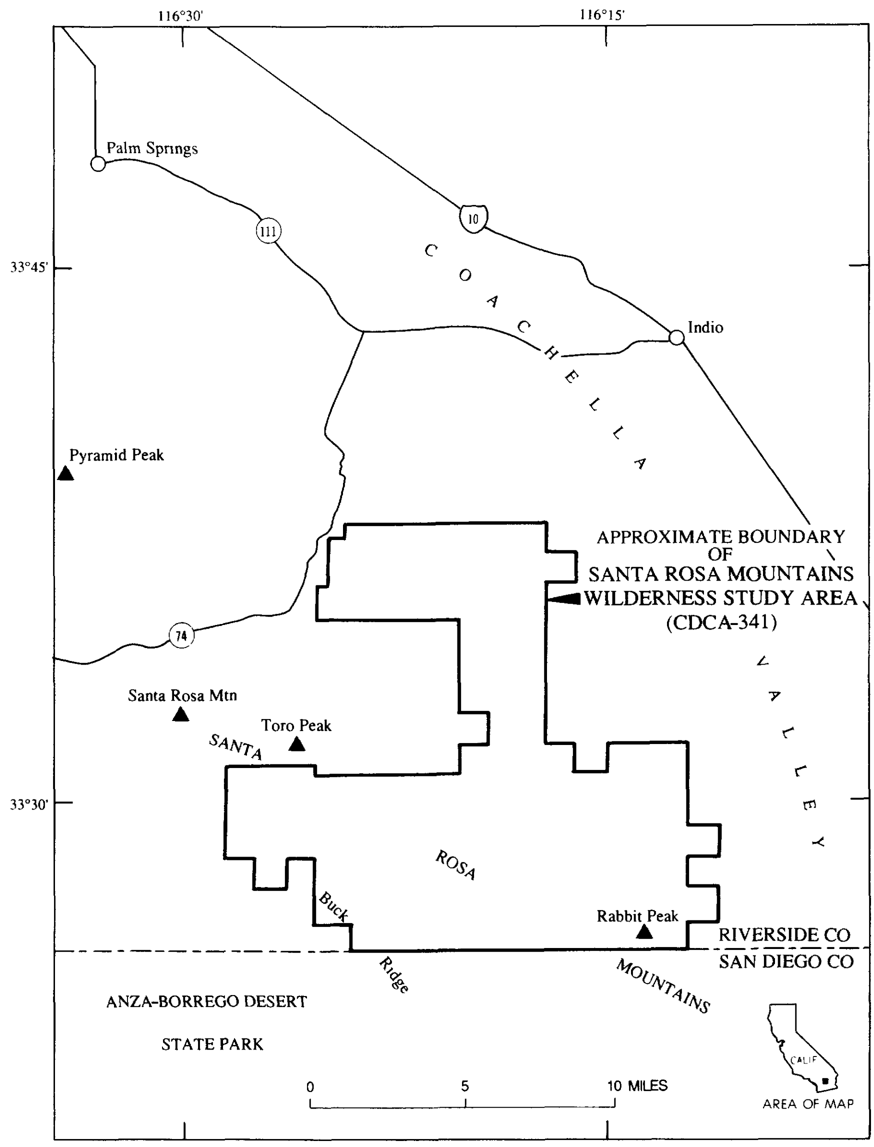

Figure 1. Index map showing location of the Santa Rosa Mountains Wilderness Study Area, Riverside County, California.

Valley. Topography of the study area is shown on the Clark Lake, Coachella, Palm Desert, and Rabbit Peak 15-minute quadrangles. Elevations range from 6,623 ft at Rabbit Peak to less than 400 ft on the west side of Coachella Valley. Most of this relief is expressed as sharp ridges and deep, steep canyons in the central part of the study area. The climate is semiarid to arid. Vegetation varies from sagebrush and desert grasses at lower elevations to pine and fir forests at the upper elevations

Previous Work

The geology within the study area was mapped by Wright (1946), Sharp (1967), and Matti and others (1983). Wright (1946) described the skarn deposits just north of the study area between Santa Rosa Mountains and Toro Peak.

Methods

The U.S. Geological Survey conducted geologic, geochemical, and geophysical studies in 1982 and in 1987 to assess the mineral resource potential of the study area. This work identified the extent and geologic controls of known mineralized areas as a guide to undiscovered mineralized areas. Geologic studies included field checking existing geologic maps and new geologic mapping at 1:24,000 scale.

A reconnaissance geochemical survey was designed to locate anomalous concentrations of elements that may be related to mineralization. Stream-sediment samples and non-magnetic heavy-mineral concentrates of the stream-sediment samples were collected from 179 sites in and adjacent to the study area. Analytical techniques are described in Grimes and Marranzino (1968).

Geophysical studies conducted within the study area include two partly overlapping aeromagnetic surveys and a gravity survey. Aeromagnetic data were obtained in 1981 on nearly east-west flightlines spaced approximately 0.5 mi apart. The Earth's normal magnetic field was removed from the data using the 1975 International Geomagnetic Reference Field updated to 1981. The data were originally gridded with a spacing of 2,000 ft and contoured with an interval of 50 nanoteslas (nT) and released by the U.S. Geological Survey (1983). These data have since been regridded by V.J.S. Grauch (written commun., 1986) with a spacing of 1,300 ft and contoured at an interval of 10 nT. Another aeromagnetic survey in the central third of the study area with the same specifications as the 1981 data is also available (U.S. Geological Survey, 1982). A comparison of the two surveys within their areas of overlap shows a sharp difference in detail, although the gross magnetic features are similar.

Published gravity data near the study area (Oliver, 1981; Oliver and others, 1981) were supplemented by new gravity stations within the study area at points of known elevation. The two sets of data were integrated, reduced to isostatic residual gravity values, and contoured at a 1-milligal (mGal) interval (Marino and others, 1987). The density of rocks collected at the new gravity stations were combined with existing density data (Baird and others, 1979) and contoured at an interval of 0.05 grams per cubic centimeter (g/cm^3).

The U.S. Bureau of Mines conducted field studies and library research in 1981 and 1982 to appraise the known mines, prospects, and mineral occurrences in and adjacent to the study area. One prospect within the study area was surveyed by compass and tape, and five samples were collected to determine representative chemical content. Mining and mineral lease records were obtained from the U.S. Bureau of Mines, U.S. Bureau of Land Management, and Riverside County files.

APPRAISAL OF IDENTIFIED RESOURCES

By R.A. Schreiner
U.S. Bureau of Mines

Mining, Oil and Gas, and Geothermal Activity

The Santa Rosa Mountains were first prospected in the late 1800's for gold (Schreiner, 1983). Gold, tungsten, marble, and asbestos were produced in the Santa Rosa Mountains, but only one tungsten prospect was found within the study area.

Federal oil and gas leases had been issued in the extreme northeast and southeast corners of the study area as of 1982, but no sites had been drilled (Matthew Shumaker, Bureau of Land Management, Indio Resource Area office, personal commun., 1983). These areas are underlain by metamorphic and igneous rocks that are not suitable reservoir rocks for oil and gas accumulation.

There are no geothermal leases in the study area, but two thermal springs and a well are located near the east boundary (Schreiner, 1983). The Coachella Valley, which borders the northern and eastern parts of the study area, is considered to be prospectively valuable for geothermal resources by the U.S. Geological Survey (Calzia and others, 1979).

Appraisal of Sites Examined

No identified mineral resources are present at the surface in the study area. Small amounts of sand and gravel exist along the east boundary of the study area on the alluvial plains forming the edge of the Coachella Valley. Due to its inaccessibility and its lack of unique properties, these sand and gravel occurrences are not classified as an identified resource. Similar material is abundant outside the study area and closer to current markets. Marble is present in thin lenses in the study area but does

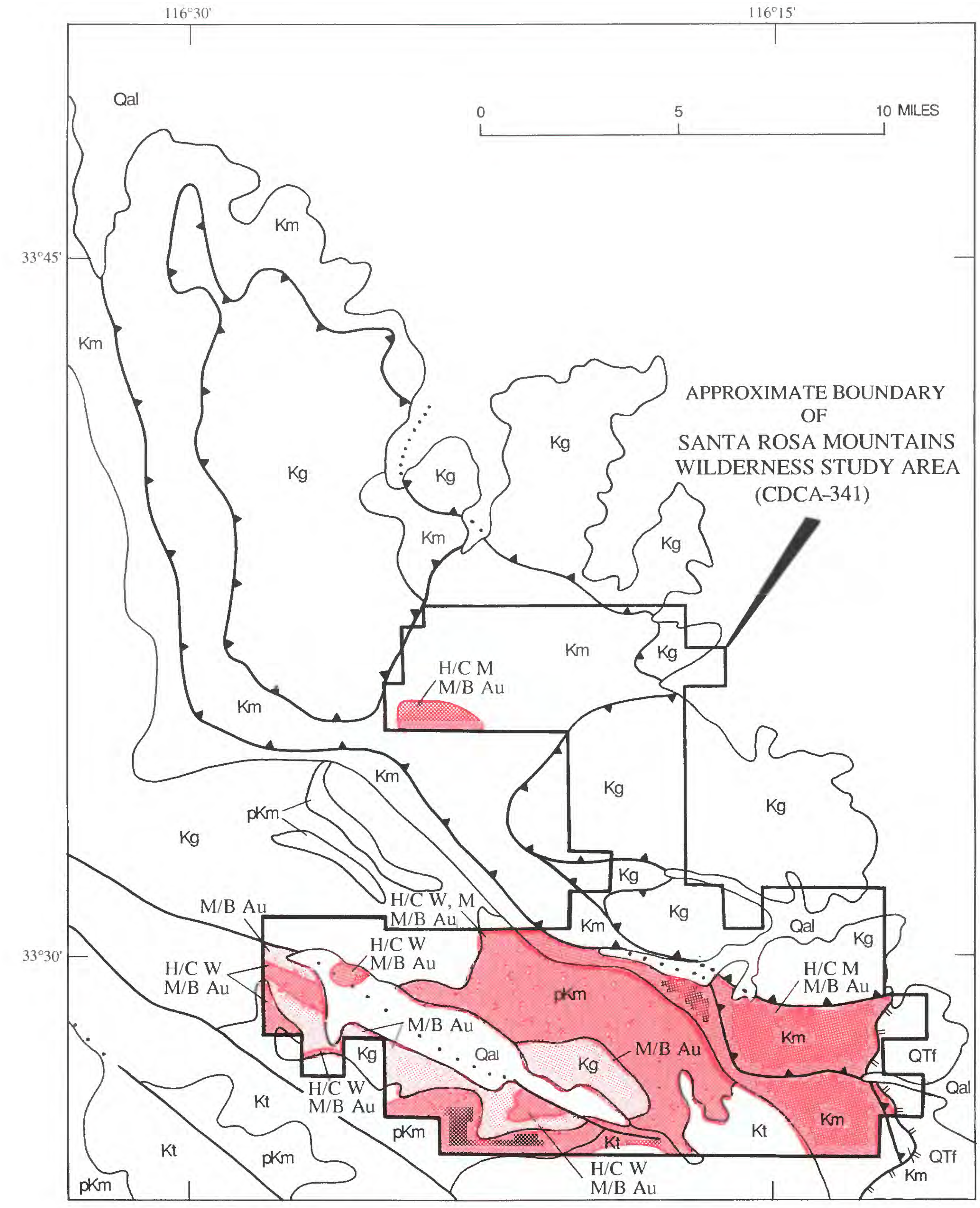

Figure 2. Mineral resource potential and generalized geology of the Santa Rosa Mountains Wilderness Study Area, Riverside County, California.

not occur in sufficient quantities to currently constitute a resource.

The Miller Ranch tungsten prospect (table 1, No. 4) in Martinez Canyon was the only prospect found within the study area. The prospect is in schistose and gneissic metasedimentary rocks that were intruded by several types of granitic rocks. The workings consist of a 30-ft-long trench, a 20-ft-long adit driven S. 23° W. to intersect a skarn within the schistose metasedimentary rocks, and a 20-ft inclined raise driven along the skarn toward a pit on the surface (Schreiner, 1983). The skarn strikes N. 50° W. and dips 48° NE., averages 2.8 ft thick, and is exposed for a length of 13 ft in the workings. The skarn contains about 100 short tons of material including garnet, calcite, quartz, secondary biotite, and sparse scheelite ($CaWO_4$). Scheelite is most abundant near the contact with the schist. Four select samples collected from the skarn contained a weighted average of 0.031 percent tungsten trioxide (WO_3). A select sample from a nearby stockpile contained 0.279 percent WO_3 (Schreiner, 1983).

EXPLANATION

Area having high mineral resource potential (H)

Area having moderate mineral resource potential (M)

Levels of certainty of assessment

B Data suggest level of potential
C Data give good indication of level of potential

Commodities

Au Gold
M Marble
W Tungsten

Geologic map units

Qal Alluvium (Quaternary)
QTf Fanglomerate deposits (Quaternary and Tertiary)
Kt Tonalite (Cretaceous)
Kg Granitic rocks (Cretaceous)
Km Santa Rosa mylonite zone (Cretaceous)
pKm Metamorphic rocks (pre-Cretaceous)

Contact
Fault—Dotted where concealed
Thrust fault—Dotted where concealed; sawteeth on upper plate
Normal fault

Figure 2. Continued.

No resources were identified at the Miller Ranch prospect (pl. 1) due to the low concentrations of tungsten and the small size of the skarn. Tungsten mining operations in the United States over the last ten years have needed a minimum grade of approximately 0.25 percent WO_3 under optimum conditions.

The Pigeon Creek and Ribbonwood prospects (table 1, Nos. 1 and 2, respectively) also contain scheelite in tungsten skarns. Wright (1946) reported that the skarns occur in thin interbeds of marble in gneiss and schist intruded by tonalite. The same intrusive relations with no known mineralization occur within the study area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By J.P. Calzia, D.J. Madden-McGuire, *and* H.W. Oliver
U.S. Geological Survey

Geology

The study area is located along the east side of the Peninsular Ranges batholith of southern California (Jahns, 1954). This batholith is of middle Cretaceous age and is the southern member of a large Mesozoic batholithic belt that extends from Baja California to Canada that includes the Sierra Nevada and the Idaho batholiths (Hill, 1984) (see appendix for geologic time chart).

Rocks within the study area (pl. 1 and fig. 2) are separated into lower and upper plates by the Santa Rosa mylonite zone of Erskine and Wenk (1985). Rocks in the lower plate include gneiss, schist, metasedimentary rocks, and grey to white marble; the rocks are intruded by the Peninsular Ranges batholith. The compositionally layered quartz-feldspar-biotite gneiss and the biotite schist contain garnet and sillimanite. The metasedimentary rocks include quartzite, hornfels, phyllite, and schist derived from a clastic marine protolith. Marble in the southern Peninsular Ranges, which is similar to marble in the lower plate, yields Ordovician conodonts (Dockem and Miller, 1982). Metamorphic mineral assemblages suggest that the pre-batholitic rocks in the lower plate were regionally metamorphosed to amphibolite grade (Gastil, 1975), probably during intrusion of the Peninsular Ranges batholith (Matti and others, 1983).

The oldest intrusive rocks within the study area form relatively small stocks and plugs of medium- to coarse-grained quartz monzonite intruded by hornblende gabbro along the crest and southwest side of Buck Ridge. The quartz monzonite is also cut by northeast-trending aplite and pegmatite dikes as well as a few quartz veins. The gabbro forms steep, sharp contacts with the quartz monzonite and is deeply weathered.

Younger intrusive rocks include tonalite, monzogranite, and granodiorite. Medium-grained tonalite con-

Table 1. Mines and prospects in and adjacent to the Santa Rosa Mountains Wilderness Study Area, Riverside County, California

Map. No. (pl. 1)	Name	Description	References
1	Pigeon Creek mine	Northwest-trending lens with scheelite in schist and garnet-epidote gouge. Lens 10 to 20 ft wide. Workings consist of 10-ft adit that trends N. 7° E., a 40- by 20- by 8-ft open cut, and 8- by 5-ft pit. Schist samples contain 0.04–0.61 percent WO_3.	Tucker and Sampson (1945); Matti and others (1983)
2	Ribbonwood prospect	Scheelite in discontinuous garnet-epidote-quartz skarn lenses at contact between tonalite and septa of mica schist. Skarn lenses strike N. 50° E. to east-west and dip steeply north. Workings include several pits, a 10- by 5- by 8-ft open cut, and a 40-ft tunnel. Selected chip samples from open cut contain nearly 2 percent $W0_3$.	Tucker and Sampson (1945)
3	Indian prospect	Scheelite in garnet-epidote skarn lens. Lens strikes east, dips 80° N., and is 600 ft long and 60 ft wide. A south-trending tunnel 150 ft long crosscuts skarn.	Do.
4	Miller Ranch prospect	Tungsten-bearing skarn lens in coarse-grained marble beds as thick as 2 in. interbedded with biotite schist. Marble and schist cut by garnet-bearing foliated pegmatite. Workings include a 20-ft shaft and 56-ft tunnel along a 2- to 7-ft-wide ore zone. Chip samples contain 0.004 to 0.098 percent WO_3. One select sample from stockpile contains 0.279 percent WO_3.	Matti and others (1983)
5	Oro Vista mine	Gold reported in quartz veins along contact between tonalite and schist. Veins strike east, dip 70° N, and are 4 to 6 ft wide. Workings include a 10-ft shaft sunk on vein and an open cut 8 ft long.	Tucker and Sampson (1945)
6	Unnamed prospect	Quartz veins that cut marble and metasedimentary rocks. Chip samples of vein contain 0.65 to 1.4 ppm gold, 20 ppm silver, and 1.0 percent copper.	
7	Unnamed prospect	Mylonitic leucogranite dikes that cut tonalite, marble, and metasedimentary rocks. Workings include a shallow trench about 8 ft long. An iron-stained chip sample contains 0.1 ppm gold and 1,500 ppm barium.	
8	Dolomite mine	White, coarse-grained marble at least 80 ft thick. Workings consist of 200- by 60-ft quarry with an 80-ft highwall.	Matti and others (1983)
9	Nightingale limestone claims	Marble	
10	Serpentine Hill asbestos claims	Narrow seams of slip-fiber amphibole asbestos in belt of serpentine that strikes north and dips 60° E. Workings include shallow shafts and open cuts.	Tucker and Sampson (1945)
11	Unnamed prospect	Shear zone with fibers of amphibole asbestos locally greater than 1 ft long.	Murdock and Webb (1956)
12	Sand and gravel pit		

tains variable amounts of hornblende, biotite, and sphene and has a seriate to porphyritic texture. Coarse-grained, generally leucocratic monzogranite contains muscovite and garnet. The granodiorite is porphyritic and is characterized by abundant mafic inclusions. These intrusive rocks grade eastward into strongly deformed mylonitic rocks characterized by a well-developed east-dipping foliation and a northeast-trending lineation.

The Santa Rosa mylonite zone of Erskine and Wenk (1985) is the northernmost segment of the Peninsular Ranges mylonite zone of Sharp (1979). The Santa Rosa mylonite zone includes more than 26,000 ft of strongly deformed cataclastic gneiss, marble, tonalite, and ultramylonite. Regional geology and small-scale structures (folds and shear planes) suggest that the Santa Rosa mylonite zone represents a southwest-directed thrust fault (Sharp, 1979; Simpson, 1984) that formed nearly synchronously with intrusion of the mid-Cretaceous plutonic rocks.

The Palm Canyon, Deep Canyon, and Martinez Mountain faults of Matti and others (1983) are part of a series of imbricate low-angle thrusts faults that are spatially related to the Santa Rosa mylonite zone (pl. 1). These thrust faults are characterized by zones of sheared, crushed, and fractured rocks that contain one or more fault surfaces with cataclastic fabrics. Sharp (1979) suggested that the mylonite zone and the thrust faults are genetically related although Matti and others (1983) reported that the mylonitic fabric is cut by the low-angle thrust faults. Dokka (1984) and Wallace (1982) reported fission track and potassium/argon ages from the mylonitic and upper plate rocks that range from 60 to 64 million years. These data represent cooling and uplift ages of the deformed rocks and suggest that the Santa Rosa mylonite zone and the closely associated low-angle thrust faults were formed from mid- to Late-Cretaceous time.

Rocks in the upper plate and structurally above the Palm Canyon fault include pelitic schist, gneiss, marble, metasedimentary rocks, and granitic rocks. The metasedimentary rocks, mapped as part of the Palm Canyon Complex of Miller (1944) by Erskine and Wenk (1985), include amphibolite and calc-silicate hornfels probably derived from a lower Paleozoic or upper Precambrian miogeoclinal protolith. These rocks are similar to the metasedimentary rocks in the lower plate except for the lack of quartzite in the upper plate.

Granitic rocks in the upper plate of the Palm Canyon and Deep Canyon faults include coarse-grained, foliated hornblende quartz diorite, granodiorite, and biotite-hornblende tonalite. The granodiorite is medium to coarse grained, foliated, and characterized by large subhedral to euhedral hornblende, magnetite, and sphene crystals as much as 0.5 in. long. Coarse-grained granodiorite and tonalite in the upper plate of the Martinez Mountain fault and an unnamed thrust fault in the northeast corner of the study area are characterized by a poorly developed foliation.

The Pliocene and (or) Pleistocene Bautista Formation of Axelrod (1966), equivalent to the "Bautista beds" of Fraser (1931), unconformably overlies the Peninsular Ranges batholith and the Santa Rosa mylonite zone. The Bautista Formation consists of poorly indurated fanglomerate deposits that were shed southwestward during uplift of the Santa Rosa Mountains.

Geochemistry

Geochemical analyses of rock and stream-sediment samples, including nonmagnetic heavy-mineral concentrates, helped delineate several areas of mineralization within the study area. Stream-sediment samples collected in dry streams that drain gneiss and schist in the lower plate contain anomalous concentrations of gold, arsenic, barium, boron, lead, and zinc. Heavy-mineral concentrates from the same area contain scheelite and yield anomalous concentrations of arsenic, barium, beryllium, copper, lead, and tungsten. A stream-sediment sample collected south of the Miller Ranch prospect (table 1, No. 4) contains 0.55 parts per million (ppm) gold; heavy-mineral concentrates from the same area contain 200 to 500 ppm tungsten and as much as 2,000 ppm arsenic.

Rock and stream-sediment samples from mylonitic rocks in the upper plate between the Palm Canyon and Martinez Mountain faults contain anomalous concentrations of gold, silver, barium, copper, tin, and zinc but no enrichment in tungsten. Rock samples from an unnamed prospect (table 1, No. 6) north of Rabbit Peak contain as much as 1.4 ppm gold, 20 ppm silver, 10,000 ppm copper, and 1,800 ppm zinc. Rock samples collected within an altered fault zone east of Rabbit Peak (table 1, No. 7) contain 0.1 ppm gold. Stream-sediment samples from this area contain 2,000 ppm tin, 2,000 ppm zinc, and a trace of silver. Scheelite is common in heavy-mineral concentrates of upper plate rocks east of California Highway 74.

Stream-sediment samples from streams that drain the coarse-grained quartz monzonite on the southwest side of Buck Ridge contain 0.95 ppm gold, 2,000 ppm barium, and 200 ppm boron. Heavy-mineral concentrates of these samples contain 300 ppm tungsten and 20 ppm copper.

Geophysics

The residual magnetic field within the study area varies from a magnetic low of –550 nT southwest of the San Jacinto fault zone to a magnetic high of –140 nT over granitic rocks in the upper plate of the Martinez Mountain fault (H.W. Oliver, unpub. data, 1987). The magnetic patterns outline three lithotectonic units: (1) tonalite and pre-batholithic rocks in the lower plate are characterized by a nearly flat magnetic field of –500±50 nT; (2) granitic rocks in the upper plate of the Martinez Mountain fault are marked by a general rise in the magnetic field from about –450 nT to –300 nT and are bounded by the –400 nT contour; and (3) mylonitic rocks in the upper plate between the Palm Canyon and Martinez Mountain faults are marked by a northwest-trending magnetic gradient bounded on the southwest by the –450 nT contour. This magnetic gradient corresponds with the southwest side of the Santa Rosa mylonite zone. The magnetic data also provide negative evidence for the otherwise possible existence of subsurface magnetite and (or) pyrrhotite occurrences, which are typically evident from magnetic surveys over similar terranes in the Sierra Nevada (Oliver, 1977, 1982).

Isostatic residual gravity values range from –42 mGal in the Coachella Valley to +6 or +8 mGal in upper plate granitic rocks (Mariano and others, 1987). The gravity relief across imbricate thrust faults in the upper plate is 12 to 16 mGal. The density of granitic rocks in the upper plate (2.77 g/cm^3) is about 0.1 g/cm^3 greater than the mean density of 2.67 g/cm^3 for tonalites in the lower plate. Assuming an infinite sheet approximation, the gravity and density data suggest that the upper plate is about 2 to 3 mi thick.

Farther to the southwest, residual gravity values decrease about 10 mGal across the San Jacinto fault zone, indicating that the fault has juxtaposed relatively low density rocks to the southwest with relatively high density tonalites to the northeast. Assuming a density contrast of 0.05 to 0.1 g/cm^3, the tonalites continue to a depth of 2 to 4 mi.

Mineral Resource Potential

Geologic and geochemical data indicate that areas of gneiss, schist, marble, and mylonitic rocks that are intruded by tonalite in the lower plate have high potential for tungsten resources at certainty level C (see appendixes for definitions of levels of mineral resource potential and certainty of assessment). Tungsten skarns often occur along the contact between carbonate and intrusive rocks (Cox, 1986). Typical skarn deposits are characterized by anomalous concentrations of tungsten, beryllium, bismuth, copper, molybdenum, tin, and zinc (Cox, 1986).

Areas containing pre-batholithic rocks in the lower and upper plates have high resource potential for marble that may be used in Portland cement and for construction materials (roofing granules, decorative stone, rip rap) at certainty level C. Marble from the Dolomite mine (table 1, No. 8) was used for roofing granules and decorative stone (Matti and others, 1983). This mine and the Nightingale limestone claims (table 1, No. 9) were inactive in 1987.

Quartz veins in an area of Cretaceous quartz monzonite along Buck Ridge, in an area of lower plate gneiss and schist, in an area of upper plate gneiss, schist, and metasedimentary rocks, and in an area of mylonitic rocks between the Palm Canyon and the Martinez Mountain faults have moderate potential for gold resources at certainty level B. Gold-quartz veins associated with the early intrusive rocks of the Peninsular Ranges batholith and the mylonitic rocks in the Santa Rosa mylonite zone are characterized by anomalous concentrations of arsenic, bismuth, copper, lead, silver, tungsten, and zinc and the absence of visible sulfide minerals. Similar geologic and geochemical characteristics occur in quartz veins that cut the Penrod Quartz Monzonite of Brown (1980, 1981) and the Desert Divide Group south of Pyramid Peak (Calzia, 1988). Here, several active gold mines are located along iron-stained quartz veins. Rocks similar to the Penrod Quartz Monzonite and the Desert Divide Group continue southeastward into the study area (Sharp, 1967).

Narrow seams of slip-fiber amphibole asbestos occur in two prospects (table 1, Nos. 10 and 11) west of the study area. No asbestos was noted along the thrust faults within the study area. There is no potential for asbestos within the study area, certainty level D.

The Bautista Formation is a possible source of sand and gravel for construction use. These deposits are thin and limited in areal extent. Larger more accessible sand and gravel deposits (table 1, No. 12) are available in the Coachella Valley closer to major metropolitan centers. Sand and gravel in the study area are not classified as identified resources (see p. 3), and there is no potential for sand and gravel at certainty level D.

The study area has no potential for oil, gas, and geothermal resources at certainty level D. The presence of structurally complex amphibolite-grade metamorphic rocks and the batholitic rocks preclude the formation of oil and gas resources. No thermal springs or geothermal indicia are present within the study area.

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LEVELS OF RESOURCE POTENTIAL

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

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

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

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

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

LEVELS OF CERTAINTY

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

LEVEL OF RESOURCE POTENTIAL →

A	B	C	D
U/A UNKNOWN POTENTIAL	H/B HIGH POTENTIAL	H/C HIGH POTENTIAL	H/D HIGH POTENTIAL
	M/B MODERATE POTENTIAL	M/C MODERATE POTENTIAL	M/D MODERATE POTENTIAL
	L/B LOW POTENTIAL	L/C LOW POTENTIAL	L/D LOW POTENTIAL
			N/D NO POTENTIAL

LEVEL OF CERTAINTY →

Abstracted with minor modifications from:

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

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

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

GEOLOGIC TIME CHART

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

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

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

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