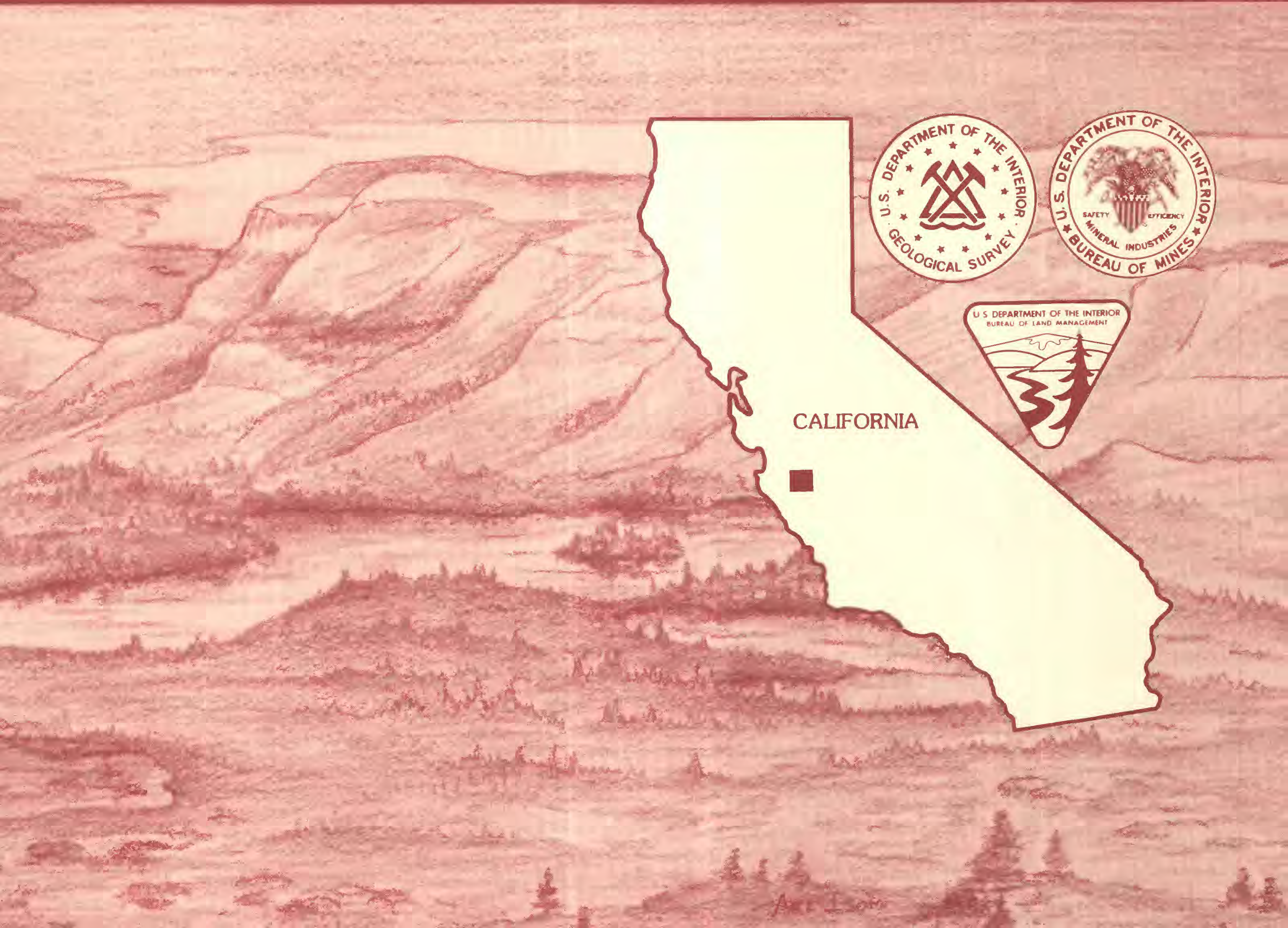
Mineral Resources of the Pinnacles Wilderness Contiguous Wilderness Study Area, Monterey and San Benito Counties, California

U.S. GEOLOGICAL SURVEY BULLETIN 1705–C



Chapter C

Mineral Resources of the Pinnacles Wilderness Contiguous Wilderness Study Area, Monterey and San Benito Counties, California

By STEVE LUDINGTON and KAREN GRAY
U.S. Geological Survey

LUCIA KUIZON
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1705

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
SOUTH-CENTRAL CALIFORNIA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1987

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

Library of Congress Cataloging-in-Publication Data

Ludington, Steve.
Mineral resources of the Pinnacles Wilderness Contiguous Wilderness Study Area, Monterey and San Benito Counties, California.

U.S. Geological Survey Bulletin 1705-C
Bibliography
Supt. of Docs. No.: I 19.3:1705-C
1. Mines and mineral resources—California—Pinnacles Wilderness Contiguous Wilderness. 2. Pinnacles Wilderness Contiguous Wilderness (Calif.) I. Gray, Karen. II. Kuizon, Lucia. III. Title. IV. Series.

QE75.B9 No. 1705-C 557.3 s 87-600298
[553'.09794'76]

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 Pinnacles Wilderness Contiguous Wilderness Study Area (CA-040-303), Monterey and San Benito Counties, California.

CONTENTS

FIGURES

Mineral Resources of the Pinnacles Wilderness Contiguous Wilderness Study Area, Monterey and San Benito Counties, California

By Steve Ludington *and* Karen Gray
U.S. Geological Survey

Lucia Kuizon
U.S. Bureau of Mines

SUMMARY

Abstract

In 1984 and 1985, at the request of the Bureau of Land Management, the U.S. Geological Survey and the U.S. Bureau of Mines conducted surveys to assess the mineral resources (known) and mineral resource potential (undiscovered) of 2,200 acres of the 5,838-acre Pinnacles Wilderness Contiguous Wilderness Study Area (CA-040-303) in the southern Gabilan Range near Hollister, Calif.. In this report, the area studied is referred to as "the wilderness study area", or simply "the study area." No active mines, prospects, or identified mineral or energy resources were identified in the study area. Two areas were determined to have low potential for mineral resources. One of these areas has low potential for gold, and silver resources. The other has low potential for diatomite and oil and gas resources.

Character and Setting

The study area consists of five parcels with a total area of 2,200 acres located about 30 mi south of Hollister, Calif. (fig. 1). These parcels are adjacent to and contiguous with the Pinnacles National Monument. The study area is located in the southern Gabilan Range, part of the Coast Ranges physiographic province. The oldest rocks in the study area are Cretaceous (144-66 million years before present, Ma) granitic rocks, which are cut by a graben (down-dropped fault block) that preserves Miocene (24-5 Ma) volcanic rocks (fig. 2) (see appendix for geologic time chart). Overlying the volcanics are Miocene marine and continental sedimentary rocks, including units formed by erosion of the older igneous rocks. Although there has been some mining activity in the area in the past, there is no present mining or exploration activity.

Identified Resources and Mineral Resource Potential

There are no active mines, prospects, or identified mineral or energy resources in the study area. Two areas have mineral or energy resource potential (fig. 2). That part of the study area that overlies the source area of the volcanic rocks, represented by a swarm of rhyolitic dikes, has low potential for gold and silver in hot-spring deposits. Those areas underlain by Miocene sedimentary rocks have low potential for diatomite in shale deposits and oil and gas resources.

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

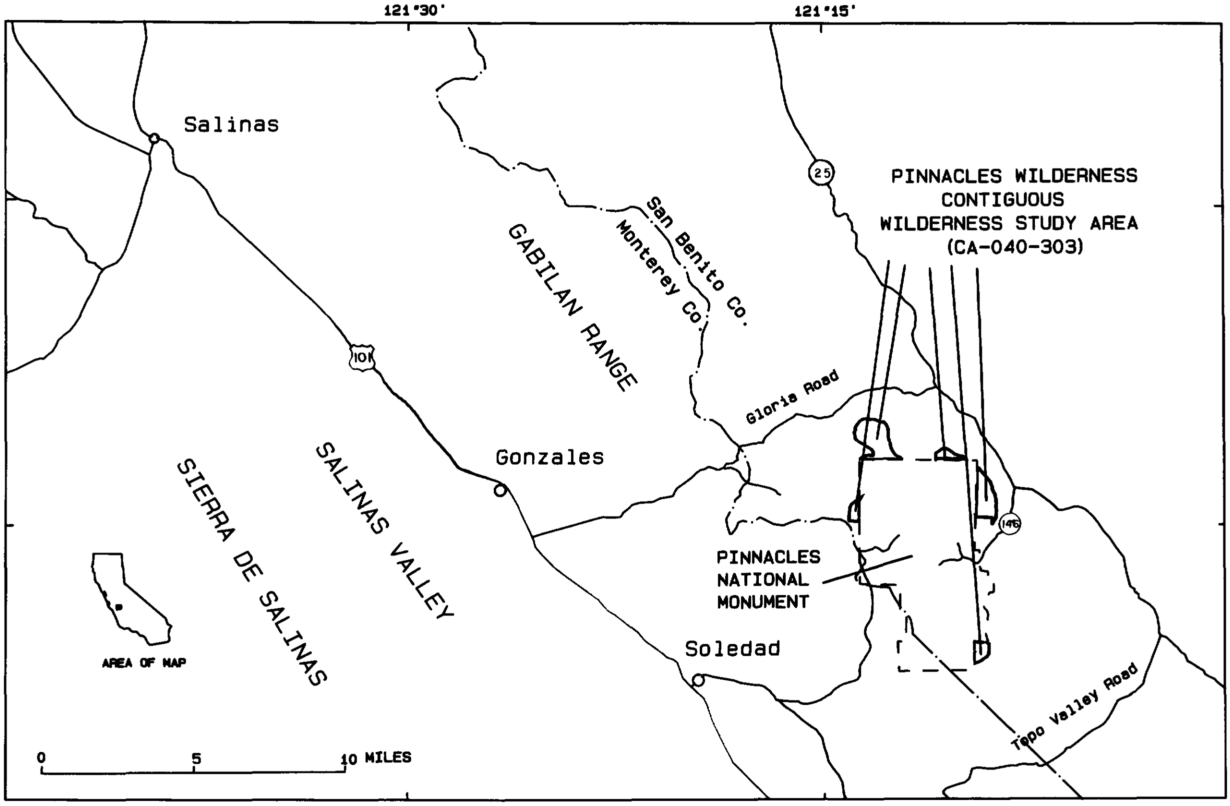


Figure 1. Index map showing location of the Pinnacles Wilderness Contiguous Wilderness Study Area, Monterey and San Benito Counties, California.

system described by U.S Bureau of Mines and U.S. Geological Survey (1980). See appendixes 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.

Location, Access, and Geography

The Pinnacles Wilderness Contiguous Wilderness Study Area (CA-040-303) is located in west-central San Benito County and east-central Monterey County, about 30 mi south of Hollister, Calif. (fig. 1). At the request of the Bureau of Land Management, five parcels totalling 2,200 acres adjacent to the Pinnacles National Monument were studied. In this report, the area studied is referred to as "the study area."

The study area is in the southern Gabilan Range, which is part of the Coast Ranges physiographic province. Access on the north is via the county-maintained gravel road (Gloria Road) in Bickmore Canyon that connects Gonzales with California Highway 25 and by private dirt roads and fire trails from the Gloria Road and California Highway 25. On the east and west, access is via California Highways 25 and 146 and private dirt roads that lead from them. Access from the south is poor; the nearest road is a county-maintained gravel road in the Topo Valley, 3 mi south of the study area.

Previous and Present Investigations

The geology of the Pinnacles National Monument and vicinity was first discussed by Fairbanks (1894). Andrews (1936) published the first detailed geologic map and description of the area. Subsequent geologic studies include Wilson (1943), Hinds (1952), Jennings and Strand (1959), Dibblee (1971, 1975), Ross (1972a, b), and Matthews (1976a, b). Descriptions of mines and prospects in or near the area were reported by Crawford (1894), Bradley and Logan (1919), Boalich (1922), Andrews (1936), Wilson (1943), Eric (1948), Butler and others (1962), Hart (1966), and Smith and others (1971). Geohydrology of the area was studied by Evenson (1962) and Akers (1967).

U.S. Bureau of Mines personnel examined the study area in May 1984 (Kuizon, 1985). Nine rock samples and five alluvium samples were collected. Rock samples were fire assayed for gold and silver, and analyzed spectrographically for 40 elements at the

Bureau of Mines' Reno Research Center laboratory. Alluvium samples were concentrated and checked for gold and other heavy metals. Diatomite samples were evaluated with a petrographic microscope. Detailed information is available from the U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Avenue, Spokane, WA 99202.

U.S. Geological Survey personnel examined the study area in May of 1985. Existing geologic maps were field checked and 40 rock samples were collected. Twenty-eight samples were analyzed using energy-dispersive X-ray fluorescence methods for manganese, iron, copper, zinc, gallium, arsenic, rubidium, strontium, yttrium, zirconium, niobium, molybdenum, tin, barium, lanthanum, and cerium. Slabs of rock samples were cut in order to study their textures.

Geologic Setting

The study area is underlain predominantly by Cretaceous igneous rocks. Cutting this basement is a graben where a series of chiefly rhyolitic rocks (Pinnacles volcanic field) are preserved. The Pinnacles and Chalone Creek faults form the west and east boundaries, respectively, of the graben. Small erosional remnants of the volcanic rocks outside the graben are found in the northern and southern parts of the study area. A northwest-trending swarm of rhyolite dikes, presumably the feeders to the volcanic field, is present in the northwestern and southeastern parts of the area. Tertiary sedimentary rocks, younger than the volcanic rocks, are found in the northern part of the area and include coarse, continental sediments and the marine Miocene Monterey Formation. Younger gravels overlie rocks in the southern part of the study area.

Acknowledgments

Harry W. Campbell, mining engineer, assisted in work done by the U.S. Bureau of Mines. The coordination with landowners, including arrangements for access, was aided by the U.S. Bureau of Land Management and the National Park Service; this was greatly appreciated.

We thank personnel of the Hollister office of the Bureau of Land Management and the Pinnacles National Monument staff of the National Park Service for their cooperation. Several private landowners provided access to parts of the study area.

APPRAISAL OF IDENTIFIED RESOURCES

By Lucia Kuizon
U.S. Bureau of Mines

Mineral-related Activity

Rhyolite containing disseminated gold was reported by Crawford (1894) at the Chalone and Defiance mines (fig. 2) in what is now the Pinnacles National Monument. Although the mine was not examined, flows and dikes sampled in this study did not contain detectable gold or any other significant metal values. A quartz pegmatite lens contained 0.03 oz/ton gold. No other pegmatite occurrences were found.

The Copper Mountain mine is located near the west boundary of Pinnacles National Monument. Workings consist of two 10-ft adits and two open cuts (Bradley and Logan, 1919). Secondary copper minerals and limonite were observed in a shear zone in altered granitic rock. No mineral production has been recorded. No similar deposits were found in the study area.

A uranium anomaly was noted in the Pinnacles National Monument by Butler and others (1962) in lapilli tuff and flow-banded rhyolite. An airborne gamma-ray spectrometer and magnetometer survey for the Department of Energy did not reveal any radioactive anomalies in the National Monument or vicinity (High Life Helicopters, Inc./QEB, Inc., 1981). A hydrogeochemical and stream-sediment reconnaissance by Cook (1981) did not indicate any anomalous mineral occurrences in the vicinity. During a reconnaissance survey with a hand-held scintillometer in 1984, no radioactive anomalies were found.

Parts of the northern and eastern parts of the study area were under oil and gas leases in the 1950's. These areas are underlain by the upper Miocene Monterey Formation, which is a favorable host for oil. A 3,239-ft wildcat well, drilled in 1951 at the north edge of the study area, was dry (Dolman, 1951). In 1984, oil and gas leases were filed east of the Pinnacles National Monument and the study area. The Bitterwater oil field lies 7 mi to the east.

Diatomaceous and siliceous shales are present in the northern part of the study area. Examination and sampling indicate that the occurrences are composed of interbedded, finely laminated tuffaceous shale, siltstone, sandstone, and ash-fall tuff, but contain few diatoms.

Numerous prospects were noted by Andrews (1936) west and southwest of the Pinnacles National Monument. The workings located in marble and tactite pendants of the Gabilan Limestone in granitic intrusive rock. Minor occurrences of tungsten, copper, and molybdenum were observed there (Laizure, 1926; Hart, 1966). These pendants do not crop out within the study area.

Identified Resources

No active mines, prospects, or mineral resources were identified in the study area. Alluvium samples were collected in the eastern and southern parts of the study area. Two of the samples contained gold values of \$0.01 and \$0.36/yd^3 calculated for a gold price of \$400/oz. A trace of native copper was observed in three of the samples. Surface sampling of other probable mineralized areas in the study area did not indicate significant mineral concentrations.

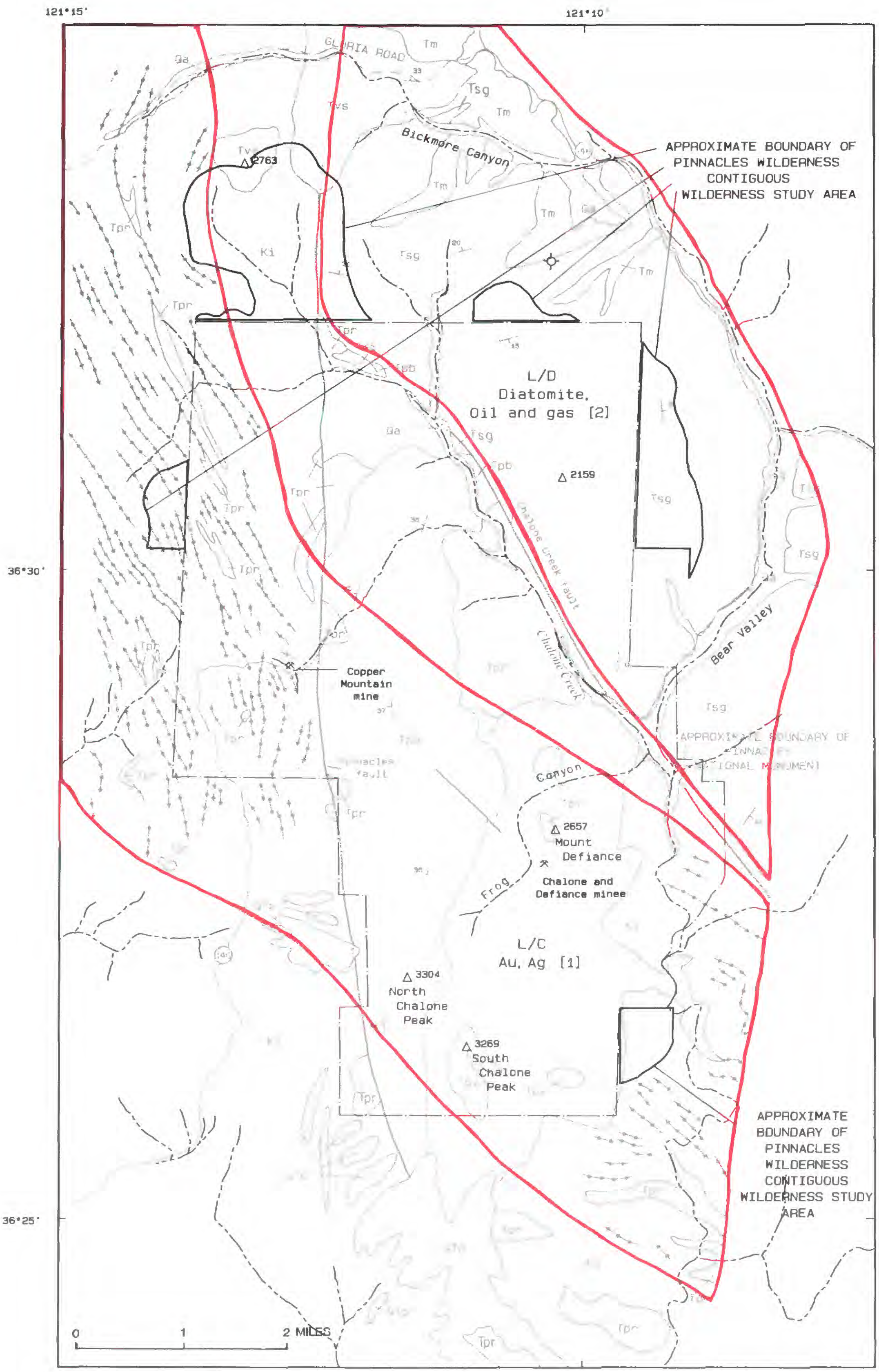


Figure 2. Mineral resource potential and generalized geology of the Pinnacles Wilderness Contiguous Wilderness Study Area, Monterey and San Benito Counties, California. Geology modified from Dibblee (1971, 1975).

EXPLANATION

Area with low mineral resource potential--See appendix for definition of mineral resource potential and certainty of assessment

Commodities

Au	Gold
Ag	Silver

[ ] Deposit types

1	Hot-spring precious-metal
2	Diatomaceous shale

Geologic map units

Qa	Alluvium (Quaternary)
QTp	Paso Robles Formation (Quaternary and Tertiary)
Tvs	Volcaniclastic sediments (Miocene)
Tm	Monterey Formation (Miocene)
Tsg	Sandstone and conglomerate (Miocene)
Tpb	Breccia of Pinnacles Formation (Miocene)
	Rhyolite dikes (Miocene)
Tpv	Vent breccia (Miocene)
Tpr	Rhyolite of Pinnacles Formation (Miocene)
Ki	Intrusive rocks (Cretaceous)

Contact
Fault--Dotted where concealed
42 Strike and dip of beds
Dry hole
Drainage

Figure 2. Continued.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Steve Ludington and Karen Gray
U.S. Geological Survey

Geology

The oldest rocks in the study area are felsic intrusive rocks, primarily of Cretaceous age, that enclose some small pendants and inclusions of metamorphic rock. They were described by Ross (1972a, b).

Overlying the Cretaceous igneous rocks is a series of volcanic rocks, assigned by Matthews (1976a, b) to the Pinnacles Volcanic Formation (Pinnacles Formation of Andrews, 1936). These rocks comprise a homoclinal, west-dipping section in a graben, bounded on the west by the Pinnacles fault and, on the east, by the Chalone Creek fault (fig. 2). Rocks from the Pinnacles Volcanic Formation were dated, using potassium-argon methods by Turner (1968), at about 23.5 Ma, or Early Miocene in age. Although Matthews (1976a) presents a more complex subdivision, these rocks may be divided into two major units, a rhyolite unit and a breccia unit.

The rhyolite unit, which is the oldest volcanic unit, consists of a series of primarily rhyolitic flows and intrusions. These flows and intrusions issued from a series of northwest-trending fissures that are represented by a swarm of rhyolitic dikes outside the graben. In a few areas, notably on South Chalone Peak (fig. 2) in the southern part of the study area, complex vent breccias are present, indicating the source of the youngest eruptions of this unit. In the central part of the study area, a small volume of more mafic rocks, dacite and andesite, is present. A few of the dikes are also dacitic in composition.

Overlying the flows and intrusions is the breccia unit, a thick section that consists primarily of rhyolitic breccias. These breccias form the spectacular pinnacles, which are the chief scenic attraction of the Pinnacles National Monument. The clasts in the breccia consist primarily of lithic fragments of the underlying rhyolitic flows and intrusions. The matrix is fine-grained volcanic material. Matthews (1976a) observed marine fossils, graded bedding, and stratification and concluded that this unit formed in a submarine environment as the result of mass slumping and turbidity currents on the flanks of an erupting vent.

Overlying the volcanic rocks is a sequence consisting primarily of continental arkose and conglomerate composed of fragments of the underlying granitic basement and debris from the Pinnacles Formation. These rocks were deformed into several open folds in the northeastern part of the area, northeast of the Chalone Creek fault. Beds there dip generally to the northeast. They were assigned a Middle Miocene age by Wilson (1943) and Dibblee (1971, 1975). Intercalated with these rocks are siliceous shales assigned to the Miocene Monterey Formation by Dibblee (1975), who also mapped a sedimentary rhyolitic breccia unit at the north end of the study area. The sedimentary breccia is composed almost entirely of rhyolitic debris from the Pinnacles Formation and represents the same depositional environment as the arkose and conglomerate, but at a time when the Pinnacles Formation was the primary source of the sediments.

A few terraces in the southern part of the area are covered with terrestrial gravels of late Pliocene or early Pleistocene age that Dibblee (1971) assigned to the Paso Robles Formation. The bottoms of many of the ephemeral stream valleys in the area are filled with river sediment of Quaternary age.

Geochemistry

Results of energy-dispersive X-ray fluorescence analysis of selected rock samples from the Pinnacles volcanic field have been reported in Ludington and Gray (1986).

The results show the Pinnacles rocks to be a typical calc-alkaline volcanic series. The rhyolites are relatively low silica (see Matthews, 1976a) and are not strongly enriched in alkalis or in incompatible trace elements such as rubidium or niobium. A few samples show perturbation of barium and strontium values, suggesting both leaching and enrichment. This is probably a result of vapor-phase alteration and does not indicate widespread hydrothermal alteration. The rock suite is enriched in arsenic. Several samples of intrusive and extrusive rhyolite have arsenic values greater than the 15 ppm detection limit. Thus, the rocks are a potential source for gold and silver deposits, which are characterized by high arsenic.

A sample of mineralized rock from the Copper Mountain mine, within the Pinnacles National Monument, shows a chemical pattern typical of epithermal gold and silver deposits related to calc-alkaline igneous rocks. It is enriched in copper, lead, zinc, and arsenic.

Mineral and Energy Resources

The Pinnacles volcanic field is an appropriate setting for hot-spring gold-silver deposits (Berger, 1985). These are found in the shallow part of young rhyolitic volcanic centers of calc-alkaline affinity that are related to subduction zones or transform faults. They are characterized geochemically by the association of arsenic and antimony with gold and silver. The geochemical signature of the samples analyzed (Ludington and Gray, 1986) is permissive for this type of deposit, and the calc-alkaline nature of the Pinnacles rhyolites is also appropriate.

Nevertheless, we assign only a low potential for gold and silver resources in hot-spring deposits in the Pinnacles volcanic field. Exposures are relatively good, and no significant areas of hydrothermal alteration that might indicate mineralization were observed. The level of certainty is C; available information gives a good indication of the mineral resource potential. Detailed geologic mapping, perhaps at a scale of 1:12,000 and lithogeochemical sampling would be necessary to raise the certainty level to D.

Other deposit types commonly found in rhyolitic rocks include volcanogenic uranium, volcanogenic beryllium, and rhyolite-hosted tin deposits. These models were considered and found to be inapplicable to the study area; they are found with high-silica alkali rhyolites, not the calc-alkaline type to which the Pinnacles rhyolites belong.

There is a low potential for diatomite resources in shale beds, with a certainty level of D. The known occurrences are well exposed, and the probability that concealed deposits exist is low.

The potential for oil and gas resources is similarly low, with certainty level D. Though the Monterey Formation is a favorable host for petroleum, the dry well drilled at the edge of the study area suggests a low potential for energy resources in this small area.

REFERENCES CITED

Akers, J.P., 1967, The geohydrology of Pinnacles National Monument, California: U.S. Geological Survey Open-File Report 67-2, 13 p.

Andrews, Philip, 1936, Geology of the Pinnacles National Monument: California University Department of Geology, Science Bulletin, v. 24, p. 1-38.

Beikman, H.M., Hinkle, M.E., Frieders, Twila, Marcus, S.M., and Edward, J.R., 1983, Mineral surveys by the Geological Survey and the Bureau of Mines, Bureau of Land Management Wilderness Study Areas: U.S. Geological Survey Circular 901, 28 p.

Berger, B.R., 1985, Geologic-geochemical features of hot-spring precious-metal deposits, in Tooker, E.W., ed., Geologic characteristics of sediment- and volcanic-hosted disseminated gold deposits--search for an occurrence model: U.S. Geological Survey Bulletin 1646, p. 47-54.

Boalich, E.S., 1922, San Benito County: California State Mining Bureau 18th Report, p. 211-220.

Bradley, W.W., and Logan, C.A., 1919, San Benito County: California State Mining Bureau 15th Report, p. 616-673.

Butler, A.P., Jr., Finch, W.I., and Twenhofel, W.S., 1962, Epigenetic uranium deposits in the United States: U.S. Geological Survey Mineral Investigations Resource Map MR-21, scale 1:3,168,000, 42 p.

Cook, J.R., 1981, Santa Cruz 1° by 2° NTMS Area, California hydrogeochemical and stream-sediment reconnaissance: U.S. Department of Energy Report GJBX-314 (81), 18 p.

Crawford, J.J., 1894, Gold-San Benito County: California State Mining Bureau, 12th report of the state mineralogist, p. 227-228.

Dibblee, T.W., Jr., 1971, Geologic map of the Greenfield quadrangle, California: U.S. Geological Survey Open-File Report 71-38, scale 1:62,500.

___ 1975 Geologic map of the San Benito quadrangle, California: U.S. Geological Survey Open-File Report 75-394, scale 1:62,500.

Dolman, S.G., 1951, District No. 3 wildcat wells, in Summary of Operations, California Oil Fields: Division of Oil and Gas, 37th Annual Report, v. 37, no. 2, 157 p.

Eric, J.H., 1948, Tabulation of copper deposits of California: California Division of Mines Bulletin 144, p. 197-357.

Evenson, R.E., 1962, Ground-water reconnaissance at Pinnacles National Monument, California: U.S. Geological Survey Water-supply Paper 1475-K, p. 375-382.

Fairbanks, H.W., 1894, Geology of Northern Ventura, Santa Barbara, San Luis Obispo, Monterey, and San Benito Counties: California State Mining Bureau, 12th Report of the State Mineralogist, p. 493-526.

Goudarzi, G.H., 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84-787, 51 p.

Hart, E.W., 1966, Mines and mineral resources of Monterey County, California: California Division of Mines and Geology County Report 5, 142 p.

High Life Helicopters Inc./QEB Inc.,1981, Airborne gamma ray spectrometer and magnetometer survey, Santa Cruz quadrangle: U.S. Department of Energy Report GJBX-50 (81).

Hinds, N.E.A., 1952, Evolution of the California landscape: California Division of Mines Bulletin 158, p. 180-181.

Jennings, C.W., and Strand, R.G., 1959, Geologic map of California - Santa Cruz sheet: California Division of Mines Map, scale 1:250,000.

Kuizon, Lucia, 1985, Mineral resources of the Pinnacles Wilderness Contiguous Wilderness Study Area (BLM No. CA-040- 303), San Benito and Monterey Counties, California: U.S. Bureau of Mines Mineral Land Assessment Open-File Report 29- 85, 12 p.

Laizure, C. M., 1926, San Francisco Field Division, San Benito County, 22nd Report of the State Mineralogist: California State Mining Bureau, p. 217-247.

Ludington, Steve, and Gray, Karen, 1986, Petrochemical studies of the Pinnacles Wilderness Contiguous Wilderness Study Area, Monterey and San Benito Counties, California: U.S. Geological Survey Open-File Report 87-135, 8 p.

Matthews, Vincent III, 1976a, Geology of the Pinnacles Volcanic Formation and the Neenach Volcanic Formation and their bearing on the San Andreas Fault problem: Santa Cruz, Calif., University of California, unpublished Ph.D. Dissertation, 213 p.

____ 1976b, Correlation of the Pinnacles and Neenach Volcanic Formations and their bearing on the San Andreas fault problem: American Association of Petroleum Geologists Bulletin, v. 60, no. 12, p. 2128-2141.

Ross, D.C., 1972a, Geologic map of the pre-Cenozoic basement rocks, Gabilan Range, Monterey and San Benito Counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-357, scale 1:125,000.

____ 1972b, Petrographic and chemical reconnaissance study of some granitic and gneissic rocks near the San Andreas fault from Bodega Head to Cajon Pass, California: U.S. Geological Survey Professional Paper 698, 92 p.

Smith, M.B., Engler, V.L., Lee, D.I., Horn, K.J., and Wayland, R.G., 1971, Reported occurrences of selected minerals in the central third of California: U.S. Geological Survey Mineral Investigations Resource Map MR-48, scale 1:500,000.

Turner, D.L., 1968, Potassium-argon dates concerning the Tertiary Foramaniferal time scale and San Andreas Fault displacement: Berkeley, Calif., University of California, unpublished Ph.D. Dissertation.

U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Ciruclar 831, 5 p.

Wilson, I.F., 1943, Geology of the San Benito quadrangle, California: California Journal of Mines and Geology, v. 39, no. 2, p. 183-270.

APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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.

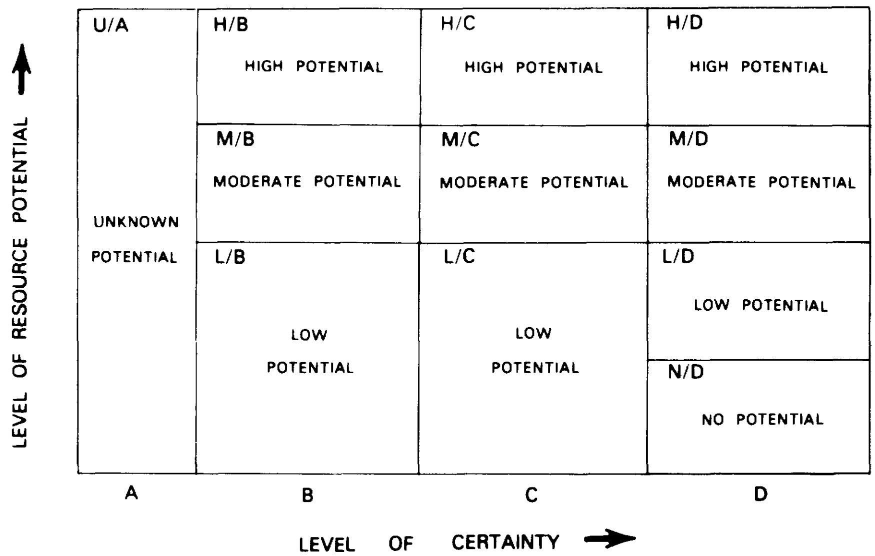
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate reasonable likelihood of resource accumulation, and (or) where an application 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.

Taylor, R. B., Stoneman, R. J., and Marsh, S. P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40–42.

Goudarzi, G. H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–0787, p. 7, 8.

RESOURCE/RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		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.

GPO 785-048/77399