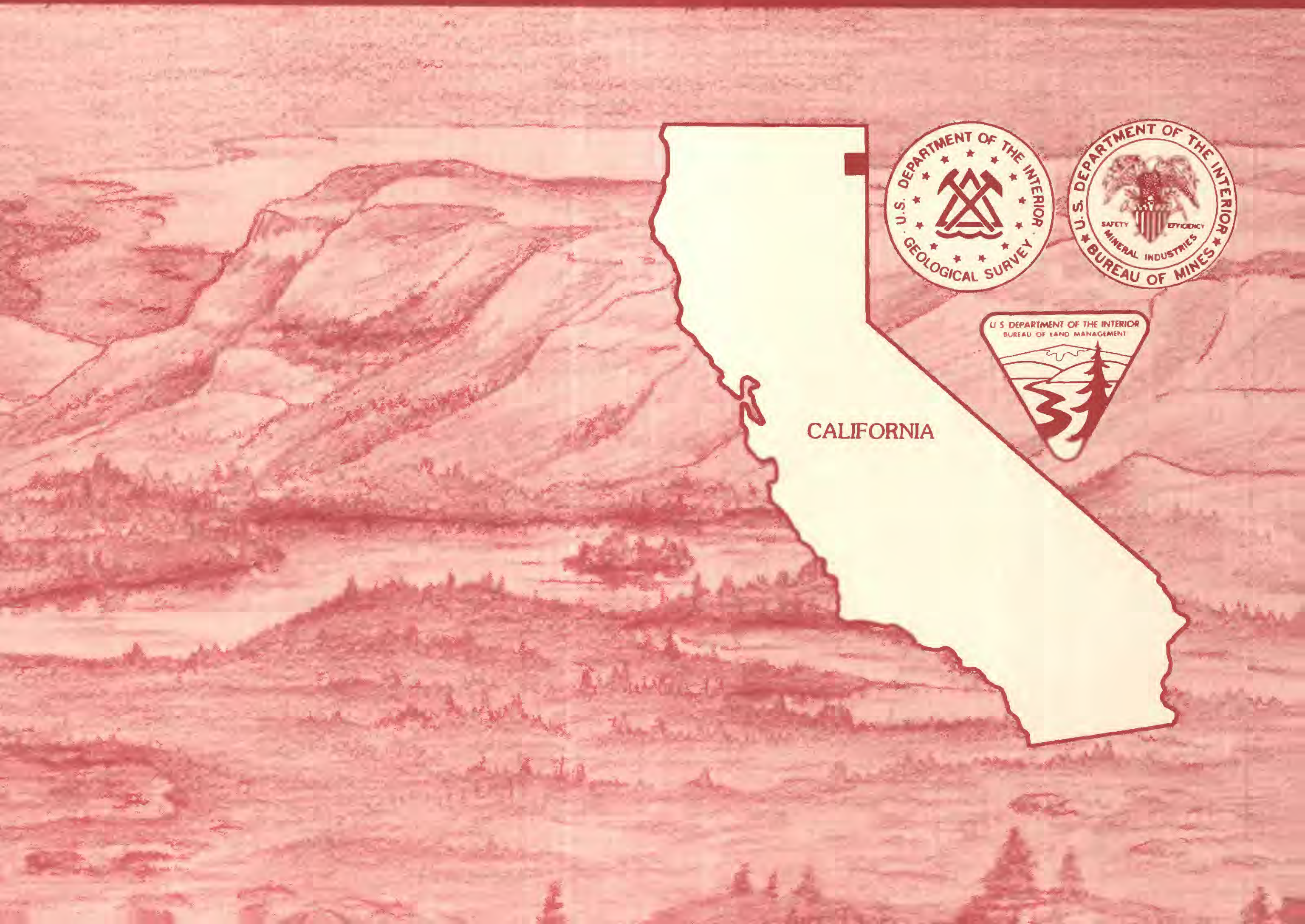
# Mineral Resources of the South Warner Contiguous Wilderness Study Area, Modoc County, California

U.S. GEOLOGICAL SURVEY BULLETIN 1706–F



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

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

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

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

## BY MAIL

### Books

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

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

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

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

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

### Maps

For maps, address mail orders to

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

Residents of Alaska may order maps from

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

## OVER THE COUNTER

### Books

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

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

### Maps

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

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

Chapter F

# Mineral Resources of the South Warner Contiguous Wilderness Study Area, Modoc County, California

By MICHAEL G. SAWLAN and JAMES G. FRISKEN
U.S. Geological Survey

MICHAEL S. MILLER
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1706

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
NORTHEASTERN CALIFORNIA AND PART OF ADJACENT WASHOE COUNTY, NEVADA

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

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

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1989

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

**Library of Congress Cataloging-in-Publication Data**

Sawlan, Michael G.
Mineral resources of the South Warner Contiguous Wilderness Study Area, Modoc County, California / by Michael G. Sawlan and James G. Frisken, Michael S. Miller
p. cm. — (Mineral resources of wilderness study areas—northeastern California and part of adjacent Washoe County, Nevada ; ch. F)(U.S. Geological Survey bulletin ; 1706–F)
Bibliography: p.
Supt. of Docs. no. : I 19.3:1706–F
1. Mines and mineral resources—California—South Warner Contiguous Wilderness. 2. South Warner Contiguous Wilderness (Calif.) I. Frisken, James G. II. Miller, Michael S. III. Title. IV. Series. V. Series: U.S. Geological Survey bulletin ; 1706–F.

| | | |
|---|---|---|
| QE75.B9 no. 1706–F | 557.3 s—dc20 | 88-600133 |
| [TN24.C2] | [553'.09794'23] | CIP |

## 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 submitted to the President and the Congress. This report presents the results of a mineral survey of the South Warner Contiguous Wilderness Study Area (CA–020–708), Modoc County, California.

# CONTENTS

FIGURES



TABLE

# Mineral Resources of the South Warner Contiguous Wilderness Study Area, Modoc County, California

*By* Michael G. Sawlan *and* James G. Frisken
*U.S. Geological Survey*

Michael S. Miller
*U.S. Bureau of Mines*

## SUMMARY

### Abstract

The South Warner Contiguous Wilderness Study Area (CA–020–708) is located along the east flank of the South Warner Mountains in northeastern California. At the request of the U.S. Bureau of Land Management, 4,330 acres of the South Warner Contiguous Wilderness Study Area was evaluated for mineral resources (known) and mineral resource potential (undiscovered). In this report, the area studied is referred to as the "South Warner Contiguous Wilderness Study Area" or the "study area."

Approximately 35 mining claims have been located in or near the study area but no claims are current; there are no mineral leases. The study area contains identified resources of geothermal energy, and sand and gravel. The Barber parcel contains a small, marginally economic, geothermal resource suitable for space heating. Sand and gravel, similar to that found in the study area within the Eagle and Barber parcels, are currently excavated from small pits located east of the study area. Uneconomic occurrences of gold, perlite, pozzolan, zeolites, carbonaceous rock, and hydrocarbons are also present. The Granger, Cottonwood, Hornback, Eagle, Barber, and Van Riper parcels contain low-grade, uneconomic gold occurrences in rock. Traces of alluvial gold are also found in the Granger and Eagle parcels.

The entire study area has low potential for epithermal (low-temperature) gold and silver resources. Evidence of epithermal mineralization consists of rock and stream-sediment geochemical anomalies of gold or elements associated with gold in present-day mineralized hot springs and related epithermal gold deposits, and alteration characterized by silicification. The Barber and Van Riper parcels in the southern part of the study area have low potential for geothermal energy resources. The entire study area has no potential for oil and gas.

Manuscript approved for publication, March 28, 1989.

### Character and Setting

The South Warner Contiguous Wilderness Study Area (CA–020–708) is located along the east flank of the South Warner Mountains in Modoc County, Calif., on land administered by the U.S. Bureau of Land Management (fig. 1). The study area comprises nine individual parcels distributed along 18 miles (mi) of the east boundary of the South Warner Wilderness, which lies within the Modoc National Forest. These parcels are located 3 to 21 mi south of Cedarville, Calif. From north to south the names of these parcels are the Granger, Milk, Cottonwood, Owl, Hornback, Eagle, Emerson, Barber and Van Riper parcels. All parcels are located on the rugged, steep, east slope of the Warner Mountains along the west side of the Surprise Valley fault zone. Elevations of the parcels range from about 4,600 to 6,700 ft (feet).

The study area is underlain by Oligocene (see appendixes for geologic time chart) to middle Miocene volcanic rocks which form a gently west-dipping (20°–25°) homocline west of the Surprise Valley fault zone (fig. 2). These volcanic rocks include andesitic volcaniclastic breccia, volcanic conglomerate and sandstone, basalt, andesite, and rhyolite lava, rhyolite ignimbrite, and andesite dikes. Volcanic conglomerate and volcaniclastic breccia are most abundant in the northernmost parcels. Rhyolite lava and ignimbrite occurs in the southern parcels, from the Eagle parcel south to the Barber parcel. These volcanic rocks are cut by two major fault sets. Tertiary volcanic strata are displaced by northeast- trending faults that were active during post-middle Miocene time prior to inception of faulting along the Surprise Valley fault zone. The north-trending Surprise Valley fault zone has been active in Quaternary time and truncates the northeast-trending fault set. Quaternary deltaic gravel deposits occur along the Surprise Valley fault zone.

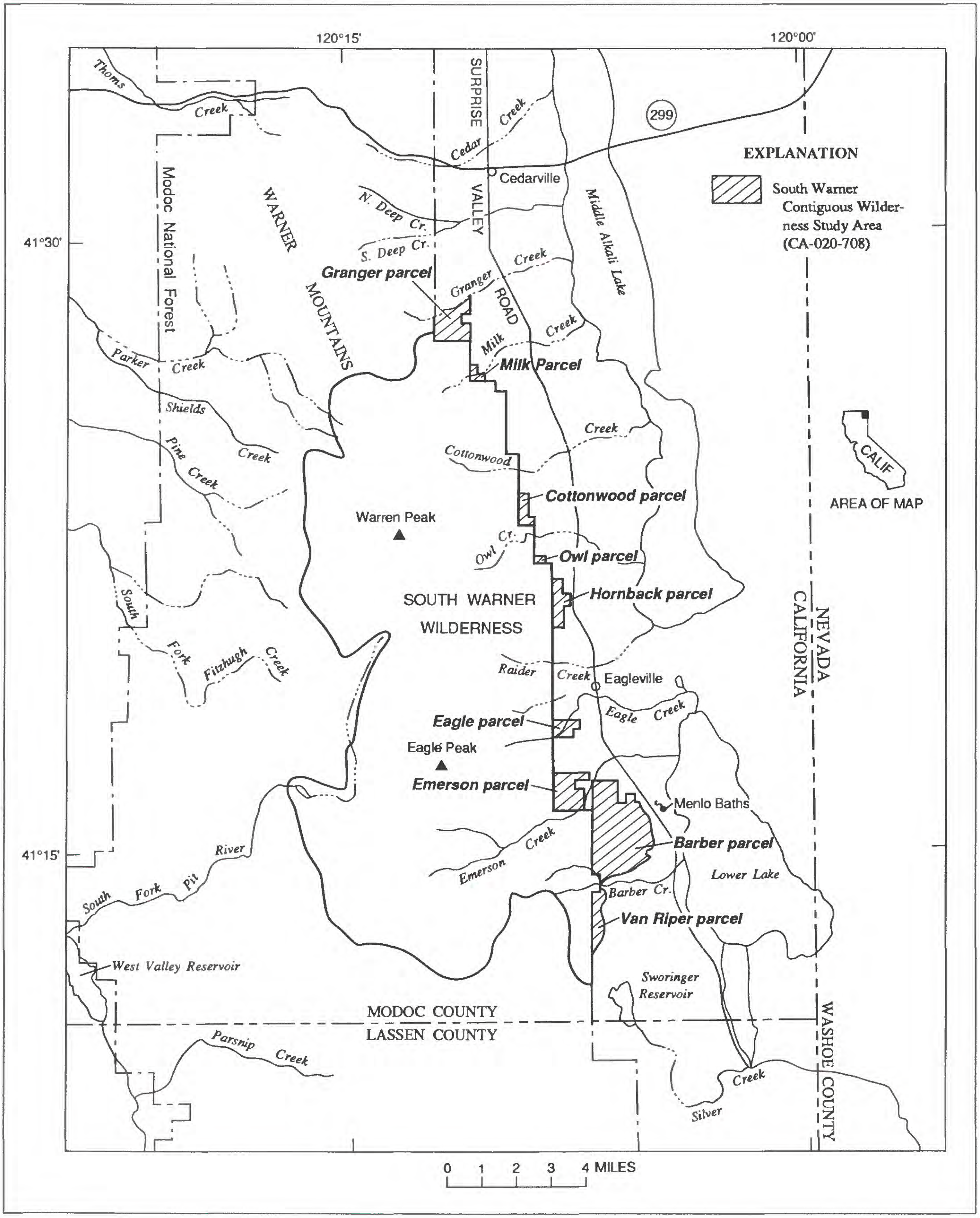



**Figure 1.** Index map showing location of South Warner Contiguous Wilderness Study Area, Modoc County, Calif.

## Identified Resources

The South Warner Contiguous Wilderness Study Area contains a small, low-temperature, marginally economic geothermal resource in and near the Barber parcel. Identified sand and gravel resources are located in and adjacent to the Eagle and Barber parcels. Gravels are currently excavated from small pits located east of the study area. County mining records show that more than 35 mining claims have been located in or near the study area. However, none of these claims is current and there are no mineral leases. No mineral exploration is presently occurring in or adjacent to the study area.

## Mineral Resource Potential

The study area has low potential for gold and silver resources in epithermal veins. Gold mineralization and related alteration and (or) geochemical anomalies are found in all parcels in the study area (fig. 2). Mineralization and alteration are strongly fracture-controlled and do not extend significantly into the wall rock outside of planar silicified zones. Mineralized areas are typically narrow (2- to 10-ft-wide), subvertical, planar to broadly lensoidal, silicified zones along north- and northeast-trending faults and (or) fractures. Locally these zones contain sulfides, limonite, and veins of barite and calcite.

Rocks containing anomalous gold concentrations are commonly silicified. The higher gold anomalies typically occur in rocks containing visible sulfide and (or) strong limonitic staining and boxwork after sulfide. Mineralized rocks contain anomalous concentrations of gold, mercury, antimony, arsenic, molybdenum, silver, cadmium, copper, boron, barium, and lead. All samples collected from the study area contain only low concentrations of gold.

The Barber and Van Riper parcels have low potential for geothermal energy resources. Warm springs are located in or adjacent to these two parcels. Although these warm springs are considered insufficient for geothermal energy development, they may be suitable for local space heating applications. The study area lies southwest of the Lake City Known Geothermal Resource Area (KGRA). No geothermal energy development has occurred in this KGRA, although 11 exploratory wells have been drilled. The entire study area has no potential for oil and gas.

# INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management and is the result of a cooperative effort by the U.S. Geological Survey and the U.S. Bureau of Mines. An introduction to the wilderness review process, mineral survey methods, and agency responsibilities was 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 the system modified from that described by McKelvey (1972) and the U.S. Bureau of Mines and U.S. Geological Survey (1980). Studies by the U.S. Geological Survey are designed to provide a 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. Goudarzi (1984) discussed mineral assessment methodology and terminology as they apply to these surveys. See appendixes for the definition of levels of mineral resource potential and certainty of assessment and for the resource/reserve classification.

## Location and Physiography

The South Warner Contiguous Wilderness Study Area (CA–020–708) is located in Modoc County, Calif., and contains nine parcels located 3 to 21 miles south of Cedarville, Calif. (fig. 1). From north to south, the nine parcels are named the Granger, Milk, Cottonwood, Owl, Hornback, Eagle, Emerson, Barber, and Van Riper parcels. These parcels encompass 4,330 acres on the lower east flanks of the Warner Mountains. The study area, administered by the U.S. Bureau of Land Management, lies along the east boundary of the South Warner Wilderness, which is part of the Modoc National Forest.

The east flank of the Warner Mountains forms a steep, rugged terrain dissected by deep, narrow canyons. Much of the study area is exposed bedrock that is locally covered by slope wash, grasses, or juniper. Foot travel in the study area is treacherous due to loose surficial gravel on mostly barren rock as well as numerous cliffs and box canyons. Vegetation in the study area is sparse except along the wider creeks, which are lined by poplars.

## Access

All parcels of the study area lie within 1.5 mi of Surprise Valley Road, a paved, county-maintained road that runs north-south along the west side of Surprise Valley (fig. 1). Graded gravel roads provide additional access to the Granger, Emerson, and Barber parcels, and several jeep trails traverse the Barber parcel. Other parcels are accessed by jeep trails across private ranch lands.

## Previous Investigations

Russell (1928) described the physiography, regional geology, and stratigraphy of the Warner Range. More

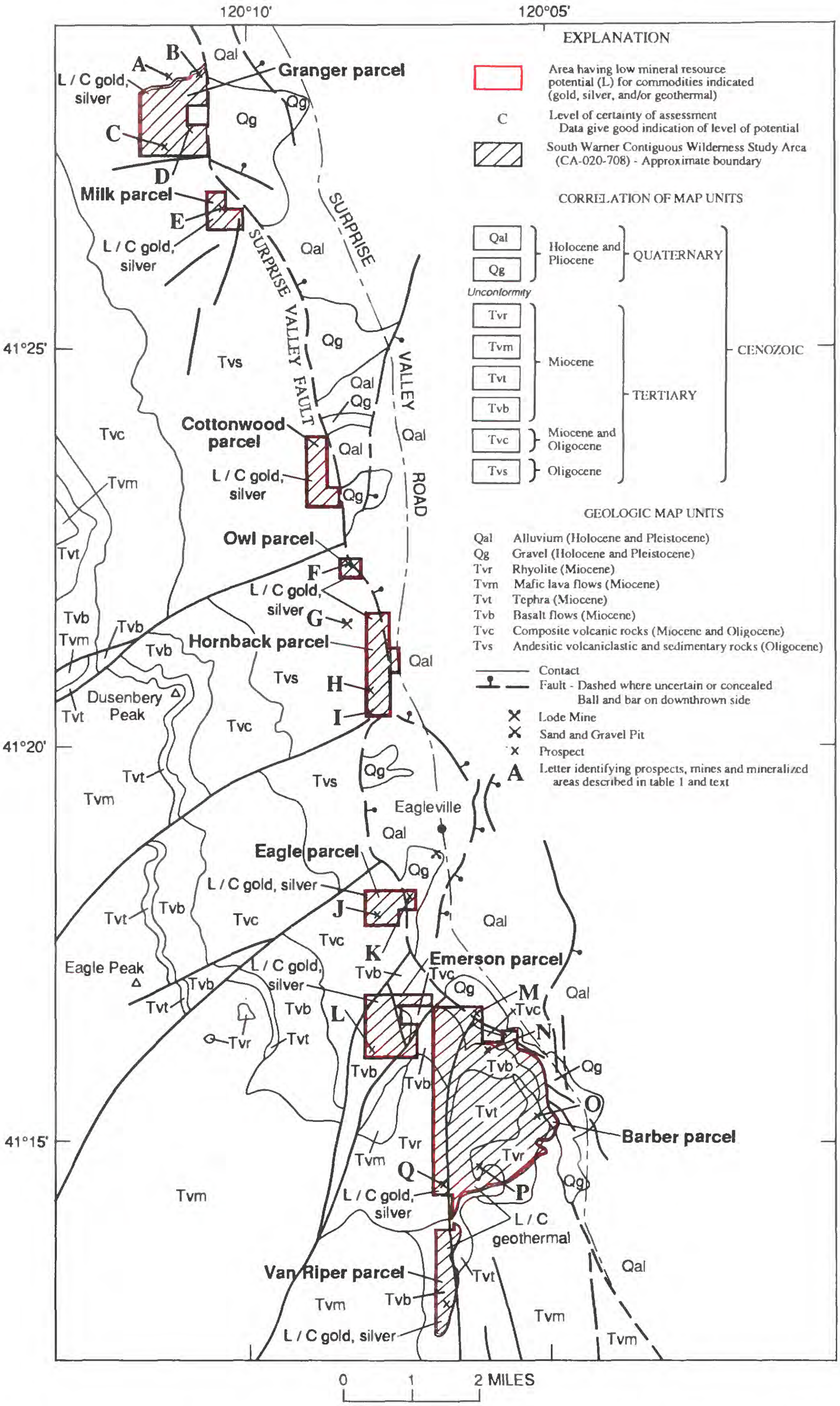



**Figure 2.** Mineral resource potential and generalized geology of the South Warner Contiguous Wilderness Study Area, Modoc County, Calif. Geology modified from Duffield and Weldin (1976) and Hedel (1980, 1981).

recently, Duffield and Weldin (1976) mapped the geology and evaluated the mineral resources of the South Warner Wilderness located adjacent to and west of the study area parcels. Duffield and McKee (1986) presented potassium-argon (K-Ar) ages and described the structure of volcanic rocks of the Warner Range. Hedel (1980, 1981) described and mapped in detail the structure of the Surprise Valley fault zone and the Quaternary geology of Surprise Valley. Geothermal resources of the Warner Mountains-Surprise Valley area have been described and evaluated by Duffield and Fournier (1974), and Hedel (1981). Tunnel (1972) has discussed the geochemistry and mineralogy of the Menlo Hot Springs located about 4 mi south of Eagleville, adjacent to and east of the Barber parcel. A gamma-ray and magnetometer survey of the Alturas 2° sheet (Aero Service Division, 1981) included the study area.

## Present Investigations

In 1986 and 1987 the U.S. Geological Survey (USGS) conducted field investigations in the study area, which consisted of checking, refining, and augmenting earlier geologic mapping, searching for altered or mineralized areas, and collecting geochemical samples. In all, 174 outcrop rock samples, 25 stream-sediment samples, 24 heavy-mineral-concentrate samples panned from stream sediment, and 10 cobble and float-rock samples collected at stream-sediment sample sites were analyzed to reveal areas having anomalous concentrations of elements of interest. All analyses were performed at U.S. Geological Survey laboratories.

Work by the U.S. Bureau of Mines (USBM) included perusal of available literature on the geology, mines, and prospects in the vicinity of the study area. Federal, state, and county records were examined to ascertain the location of mines or mineral claims in the study area. Field studies, conducted in 1987, included the examination, mapping, and geochemical sampling of prospects, claims, and mineralized areas in and adjacent to the study area; 31 alluvial and 134 rock samples were collected. The alluvial samples were concentrated and examined for economic minerals. Mineralized rock samples were analyzed for a suite of elements related to formation of mineral deposits. Samples from nonmetallic sources with likely industrial uses were analyzed with respect to their pertinent physical properties. Sampling procedures and results of the USBM investigations of the study area are described by Miller (1988). Sample data are available at the Western Field Operations Center, E. 360 Third Ave., Spokane, WA 99202.

## Acknowledgments

Terry J. Close, William N. Hale and John R. Benham (U.S. Bureau of Mines, Western Field Operations Center, Spokane, WA), and Joseph McFarlan (U.S. Bureau of Land Management, Cedarville, CA) assisted M.S. Miller in the field. Logistic support from the U.S. Bureau of Land Management and the U.S. Forest Service is gratefully acknowledged.

# APPRAISAL OF IDENTIFIED RESOURCES

*By* Michael S. Miller
*U.S. Bureau of Mines*

## Mining and Exploration History

There is no record of mineral production within the South Warner Contiguous Wilderness Study Area. Approximately 35 mining claims have been located in or near the study area, but none of these are currently active. These claims were nearly all staked in the late 1800's and early 1900's. At least six of these claims were oil and gas placers, and at least one was a coal placer claim[1]. Mines, prospects, mineralized areas, and industrial mineral occurrences located in or near the study area are shown in figure 2 and described in table 1. Sample localities and analytical results are presented in Miller (1988).

The nearest mine with recorded production is the Bagley mine (fig. 2, area G). About 1,000 oz of Iceland spar (optical-grade calcite) was mined at the Bagley mine in 1920–1921; an unrecorded amount was mined during the early 1940's, and 1,000 lb of calcite was mined during the late 1940's (Gay, 1966; Duffield and Weldin, 1976). The calcite deposit at the Bagley mine does not extend into the study area.

Total sand and gravel production from borrow pits along the highway between Cedarville and Eagleville (fig. 2) is unknown, but 4,000–10,000 $yd^3$ (cubic yards) per year was the estimated production rate in 1987 (Dale Goodwin, Goodwin Sand and Gravel, Cedarville, Calif., oral commun., 1987).

Other nearby mining or prospecting has been from mercury, obsidian, pumice, perlite, peat, and some salt deposits (Duffield and Weldin, 1976; Gay, 1966). Placers were mined along Eagle Creek (fig. 2, area J) in the late 1800's and early 1900's. An estimated 40,000 $yd^3$ of gravel was excavated, presumably for gold; it is not known how much, if any, gold was recovered. An unnamed, abandoned mercury prospect, located about 2 mi north of the Granger parcel between North Deep Creek and South Deep Creek, is marked by several shallow pits and the rusted remains of a retort. It was probably worked in the 1950's during a period of federal price supports for mercury.

[1]The oil and gas placer claims were not for alluvial materials; prior to the Mineral Leasing Act of 1920, certain mineral commodities such as gas and coal were claimed as placer locations.

In Surprise Valley, geothermal energy resources located 5 to 35 mi east and north of the study area are gradually being developed for space heating and aquaculture (Joseph McFarlan, BLM, Cedarville, Calif., oral commun., 1987). Hot springs adjacent to the study area at Menlo Baths are currently used sporadically for bathing. Warm springs, with temperatures of 64°–65° F, (fig. 2, area Q) flow within and near the study area, north of Barber Creek, but are not currently utilized.

Several widely scattered, volcanic-hosted epithermal gold mines and prospects occur in the region surrounding the study area. These include the Hayden Hill, Winters, and High Grade mines and districts in northeastern California, which produced about $3.5 million in gold and silver in the late 1800's and early 1900's (Duffield and Weldin, 1976), and the Hog Ranch mine in Nevada, which has recently been developed. These mines are located 30–50 mi from the study area. Only the Hayden Hill and Hog Ranch properties are currently operating. Within the past several years, exploration companies have been reevaluating the High Grade district, located 35 mi north of Cedarville, which has remained inactive since the turn of the century following selective mining of high-grade zones.

## Prospects, Claims and Mineral Occurrences

The study area contains a small, low-temperature, identified geothermal resource in and near the Barber parcel and identified sand and gravel resources located mainly in or near the Barber and Eagle parcels. Metallic mineral occurrences in the study area are related to uneconomic occurrences of gold. Nonmetallic commodities include uneconomic occurrences of perlite, pozzolan, and zeolites. Low-quality, noncommercial perlite and pozzolan occurrences are located in the Emerson and Barber parcels. Zeolites exist in all parcels in small veins; the largest occurrence of zeolite is in amygdules in basalt lava in the Emerson, Barber and Van Riper parcels. None of the occurrences of zeolite are suitable for commercial development and use. Trace amounts of hydrocarbon are found in sparse occurrences of weakly carbonaceous volcaniclastic rocks.

## Gold

Gold occurrences in samples collected by the U.S. Bureau of Mines from silicified zones and altered volcanic rocks within the Granger, Cottonwood, Eagle, Barber, and Van Riper parcels were determined to be uneconomic. Samples were analyzed for gold by a commercial laboratory using an instrumental neutron-activation method having a detection limit of 5 ppb (parts per billion). Five of eight rock samples adjacent to and north of the Granger parcel (fig. 2, area A) contain small amounts of gold, as much as 170 ppb. A sample of silicified rock from the northeast corner of the Granger parcel (fig. 2 area B) contains calcite veins having 9 ppb gold. Some samples of volcanic rock from sites in or near the Cottonwood, Eagle, Barber, and Van Riper parcels contain as much as 6 ppb gold. All areas are too weakly mineralized, by factors of at least ten, to be economic.

Alluvium in and near the study area contains a trace of free gold: a single microscopic flake of gold estimated to weigh less than 0.005 mg was found in each of two 0.3 $ft^3$ (cubic feet) alluvial samples (fig. 2, areas A and J) from the Granger and Eagle parcels. Alluvium at these two sites is estimated to contain less than 0.00002 troy oz of gold per $yd^3$, worth about 1 cent per $yd^3$ at a gold price of $450 per troy oz (ounce). The alluvium has no economic value as a gold placer.

## Nonmetallic Commodities

### Perlite

Perlite occurs in small outcrops (10–100 ft across) of rhyolite in the Barber parcel. Perlite is hydrous obsidian that can be heated to near-molten temperatures and expanded into a lightweight, glassy foam. Expanded perlite is commonly used in the manufacture of insulation and low density construction materials. Two perlite occurrences (fig. 2, area Q) are each estimated to be about 100 ft long, 25 ft wide, and 25 ft thick. Using a weight factor of 150 $lb/ft^3$ (pounds per cubic feet), 10,000 tons of perlite may exist in the study area.

Perlite from the Barber parcel has substandard expansion and brightness properties. Expanded density of the perlite is 10.44 $lb/ft^3$, marginal when compared to the expanded density of standards, about 3 $lb/ft^3$. Brightness is also low, about 51.6 percent, compared to brightness of 67.1 to 69.4 percent for the standards. Furthermore, the size of the occurrence is too small to be economic. Perlite from the Barber parcel is therefore unsuitable for use as commercial perlite and the perlite localities are classified as uneconomic occurrences.

### Pozzolan

Light-colored, rhyolitic, welded and unwelded tuffs in the southern part of the study area (fig. 2, area O) have the general chemical characteristics of pozzolans (American Society for Testing and Materials, 1985), natural materials that can be used as extenders or modifiers with portland or other mineral cements. Most rhyolitic tuff in the study area is located in the Barber parcel and can be traced over an area of about 2 $mi^2$ (square miles) extending northwest into the Emerson parcel. Tuff in the Barber parcel is unsuitable for pozzolan because it is mostly strongly indurated welded tuff having a hardness equivalent to lava; the hardness of this rock would present difficulties in mining and processing. In addition, tuff in the study area has no special physical or chemical properties compared to tuff that covers vast tracts of land throughout the Great Basin in Nevada and Oregon.

#### Sand and Gravel

Identified sand and gravel resources of the study area are located in deltaic gravel deposits along the east boundaries of the parcels. Most gravel deposits are located outside the study area; only a small fraction of these deposits is included inside the study area. For example, a terrace near the mouth of Eagle Creek (fig. 2, area K) includes an estimated 36 million $yd^3$ of sand and gravel, of which only 2.5 million $yd^3$ lie inside the Eagle parcel. Near the mouth of Emerson Creek (fig. 2, area M), deltaic gravel deposits encompass an inferred 31 million $yd^3$ of sand and gravel, of which only 6 million $yd^3$ lie inside the Barber parcel. More than 100 million $yd^3$ of terrace sand and gravel are estimated to exist adjacent to the Granger and Milk parcels, but less than 1 million $yd^3$ may exist inside the study area at scattered sites. Small occurrences of sand and gravel (less than 10,000 $yd^3$) also occur in the narrow, steep drainages of the study area, but these materials are poorly sorted and inferior in quality to the deltaic gravels.

The terrace sand and gravel are cleaner (have a lower silt and clay content) than alluvium in Surprise Valley. This terrace sand and gravel contains less than about 5 percent silt or clay, although washing, sizing, and removal of some undesirable material may be necessary (Dale Goodwin, Goodwin Sand and Gravel, Cedarville, Calif., and Gene Cooper, Whitepine Ranch, Eagleville, Calif., oral commun., 1987).

Deltaic terrace sand and gravel deposits inside and adjacent to the study area are probably similar in quality to sand and gravel currently mined nearby at several pits along Surprise Valley Road. However, access to the deposits within the study area is poor and, in some cases, is restricted by enclosure within private lands. It is unlikely that the study area deposits would be mined in preference to other deposits along the highway within the foreseeable future. Therefore, the estimated 8.5 million $yd^3$ of sand and gravel within the Eagle and Barber parcels are classified as an inferred subeconomic reserve.

#### Zeolites

Zeolite in the study area occurs as fine- to coarse-grained aggregates that form amygdules in lava and narrow veins along fractures in the volcaniclastic rocks. Amygdular basalt lavas underlie an estimated 2 $mi^2$ of the study area in the Emerson, Barber, and Van Riper parcels. In area N, (fig.2) the amygdules contain the zeolites phillipsite, thomsonite, analcime, chabazite, stilbite, and natrolite. Zeolites typically comprise about 5–15 percent of the lavas; some select samples may contain 30–40 percent zeolite. The amygdules are mostly less than 0.25 in. (inch) across although some exceed 1 in. in diameter. The zeolite veins commonly occur with calcite and are typically less than 2 in. thick.

Certain natural zeolites are used as chemical sieves for their ability to selectively absorb and release cations or anions. Zeolitic rocks occurring in the study area have cation exchange capacities of less than 0.61 millimole equivalents per gram. This exchange capacity is lower than that of commercially mined zeolites that do not require beneficiation, as would zeolites in the study area. Ammonium cation exchange capacity of 2 millimole equivalents per gram of sample is desirable, and 1.0 to 1.5 millimole equivalents per gram are commonly the lowest acceptable values. The zeolites in the study area are classified as small, low-grade occurrences because they have a low cation exchange capacity, and their occurrence in veins and amygdules requires beneficiation. No amygdular zeolite occurrences in basalt have ever been mined commercially.

## Energy Resources

#### Geothermal Energy Resources

The study area is located near the Lake City-Surprise Valley Known Geothermal Resource Area (KGRA) (Hedel, 1981). No commercial development of geothermal energy resources has taken place in this KGRA. The study area has neither geothermal leases nor applications and has not been explored for geothermal energy resources. An exploratory geothermal well drilled about 3.5 mi east of the Milk parcel (sec. 11, T. 41N., R. 16E.; 7,000 ft depth) did not lead to commercial development of geothermal energy resources and was abandoned. Ten other exploratory wells drilled in Surprise Valley north and northeast of the study area are either idle or abandoned (Hedel, 1981).

There are several warm springs in and near the Barber parcel, and many hot springs lie outside the study area in Surprise Valley (Slosson, 1974; Woods, 1974; Hedel, 1981; Majmundar, 1983, 1984). Surface temperatures of two warm springs in the Barber parcel were measured during this study. The warm spring located in the study area about 700 ft north of Barber Creek (fig. 2, area Q) is 64 °F, and the warm spring located on the north bank of Barber Creek about 1,100 ft west of the study area is 65 °F. The area of influence of these warm springs is estimated to be at least 0.06 $mi^2$, about one-half of which is in the study area. Estimates of temperatures at depth could not be made for the warm springs. Flow rates of the two warm springs were visually estimated at between 5 and 50 gallons per minute.

**Table 1.** Mines, prospects, claims, and mineralized areas in and near the South Warner Contiguous Wilderness Study Area, Modoc County, Calif.

| Map letter (fig. 2) | Name | Summary | Workings and production | Sample and resource data |
|---|---|---|---|---|
| A | Granger claim group | Andesitic tuff-breccia cut by quartz veins along faults and shear zones. North to northeast trending, high-angle, lenticular veins, as much as 10 ft wide and 500 ft long contain 20 pct to 90 pct fine-grained white quartz and angular silicified fragments of wallrock. Some limonite staining and some vuggy quartz. Calcite, barite and zeolites are minor constituents. Wallrock between major veins infused by quartz veinlets and lightly stained by limonite. | Two small pits or trenches. | Seven chip samples, one grab sample, and one alluvial sample were taken. Maximum gold content was 170 ppb (parts per billion). Other samples with detectable gold contained 6, 9, 21, and 24 ppb. The alluvial sample contained a trace of gold, about 0.00002 oz/yd$^3$ (troy ounces per cubic yard), worth about 1 cent per yd$^3$ *. No economic amounts of any element were detected. |
| B | Captain, Canteene, Surprise claims | Quartz-calcite-zeolite vein as much as 4 ft thick, nearly vertical, striking N40°–50°E.; hosted by andesitic tuff-breccia. Minor limonite and chlorite along vein and in wallrock. | Small trench. | Three chip samples and one alluvial sample were taken. One rock sample contained 9 ppb gold, the rest <5 ppb. The alluvial sample contained no detectable gold. No economic amounts of any element were detected in any of the samples. One of the rock samples contained traces of hydrocarbons. |
| C | Mammoth Cave, Bismark, Acma, Cosmopolitan claims | Andesitic tuff breccia cut by calcite-quartz-zeolite veins and limonitic shear zones. Mudstone hostrock is limonitic and may have been a soil horizon for small petrified logs. | Small pits. | Seven chip and two alluvial sample were taken. No economic amounts of any element were detected in any of the samples. Three rock samples contained traces of hydocarbons. |
| D | Rouse Rock, White Metal Queen lode claims; Deep Creek, Sylvia, Galdia oil placers | Andesitic tuff breccia and basaltic dikes and sills; veins and veinlets of zeolites, quartz, and calcite. Limonite staining is widespread. | None. | Three chip samples and one alluvial sample were taken. No economic amounts of any element were detected. One rock sample contained traces of hydrocarbons. |
| E | Hedgepath and Summit Slide lode claims; Granger, Monarch, and Dolphin oil placers | Limonitic, sheared, andesitic tuff breccia. | None. | Six chip samples, one grab sample, and one alluvial sample were taken; no economic amounts of any element were detected. One rock sample contained traces of hydrocarbons. |
| F | Spar 1–2 claims | Sheared, limonitic zone in andesitic tuff breccia. | None. | A chip sample was taken; no economic amounts of any element were detected. |
| G | Bagley mine (Ocheo, Big Molley, Iceberg Spar groups) | Calcite-rich veins in andesitic tuff breccia. Possible optical-grade calcite crystals and cleavage fragments. Some limonite staining and alteration on wallrocks. | Two trenches about 50 ft long and at least four small pits or trenches. About 1000 oz of optical calcite were produced in 1920 and 1921. An unknown amount was produced in the early 1940's and about 1,000 lb of chemical grade calcite was produced in the late 1940's. | Two chip samples and one grab sample were taken; no economic amounts of any element were detected. No optical calcite was found. |

**Table 1.** Mines, prospects, claims, and mineralized areas in and near the South Warner Contiguous Wilderness Study Area, Modoc County, Calif.—*Continued*

| Map letter (fig. 2) | Name | Summary | Workings and production | Sample and resource data |
|---|---|---|---|---|
| H | Lazarus claim | Andesitic tuff breccia with andesite and basalt dikes. Some sheared zeolitic and calcitic veins. | None | Ten chip samples and one alluvial sample were taken; no economic amounts of any element were detected. |
| I | Rattlesnake, McCulley, Mabel claims | Andesitic tuff breccia; some mafic dikes. Much calcite, zeolite, and quartz vein material along dikes and fractures. Abundant limonite staining. | None | Six chip samples and one alluvial sample were taken ; no economic amounts of any element were detected. |
| J | Eagle, Cornucopia 1–2, Silver Eagle claims | Andesite lava and rhyolite ignimbrite; basaltic dikes and sills, some sheared. Limonitic staining locally abundant. Some local chloritic and argillic (?) alteration. | Two areas of placer mining; at least 20,000 $yd^3$ mined within the study area, and 20,000 $yd^3$ outside and adjacent to the east. | Eight alluvial samples were taken; one had a trace of gold, about 0.00002 oz/$yd^3$, worth an estimated 1 cent per $yd^3$ *. Eleven chip samples and four grab samples were also taken. One sample had 6 ppb gold. No economic amounts of any element were found. |
| K | Eagle Creek sand and gravel | Bench gravel in the southeast part of the Eagle Creek parcel contains rounded to subangular cobbly, pebbly, sandy gravel from volcanic source rocks. | None within study area; sand and gravel pit in extension of same deposit at Eagleville. | An estimated 2.5 million $yd^3$ of sand and gravel within the study area and 33.5 million $yd^3$ adjacent and to the northeast. |
| L | Holden Dick, Lorel claims | Basalt lava, dikes and sills, and rhyolite ignimbrite. Much zeolite, calcite, and quartz filling in vesicles and fractures. Some moss agate. | None | Six chip samples, two grab samples, and four alluvial samples were taken; no economic amounts of any element were detected. |
| M | Barber Creek sand and gravel | Bench gravel in the Barber Creek parcel contains sand and gravel derived from volcanic source rocks. | None | An inferred 6 million $yd^3$ of sand and gravel within the study area and 25 million $yd^3$ adjacent to the north and east. |
| N | Zeolite occurrences | Amygdular basalt locally contains at least 50 pct zeolites, mainly phillipsite, thomsonite, analcite, and chabazite; accompanying minerals are calcite, quartz, chlorite, and epidote. | None | Zeolitic rock underlies about 2 $mi^2$ (square miles) of the Emerson, Barber, and Van Riper parcels. Cation exchange capacity of 31 whole-rock samples is uneconomically low, less than 0.61 millimole equivalents per gram. |
| O | Pozzolan occurrences | Hard to friable rhyolite ignimbrite and pumiceous tuff. | Small pits | Four samples contained an average of 62 pct $SiO_2$, 15 pct $Al_2O_3$, and 4 pct $Fe_2O_3$, and had an average loss on ignition of 8 pct . The tuffs crop out over about 2 $mi^2$ of the Barber parcel and extend into the Emerson Parcel. |
| P | One-hundred claims | Rhyolite tuff with some limonite staining and silicification(?). Some knobby, rounded, siliceous nodules in the rhyolite. | Pit 9 ft by 7 ft by 3 ft. | Three chip samples were taken. One contained 6 ppb gold. No economic amounts of any element were detected. |
| Q | Jasper and Agate claims | Rhyolite lava, banded and nodular, with silicification and limonite staining. Some obsidian and perlite. Warm springs with temperatures of 64°–65°F are inside the study area and adjacent to the west. Other springs nearby flow at 47°–55°F. | Small pits and trenches, at least one short adit. | Seven chip samples, three grab samples and two alluvial samples were analyzed. No economic amounts of any element were detected. Perlite occurrences total about 10,000 tons in the study area. |

*Gold assumed 1,000 fine, and gravel assumed to expand 25 pct on excavation. Gold price assumed $450/ troy ounce.

Warm springs in and near the Barber parcel may be suitable for small-scale, low-temperature space heating. The Barber parcel contains a small, marginally economic, geothermal resource suitable for space heating.

Hot springs outside the study area at Menlo Baths, located about 1,200 ft east of the Barber parcel, have surface temperatures of 127°–138 °F and flow at rates of several thousand gallons per minute (Hedel, 1981). The surface temperatures of most of the other springs in or near the Barber Creek and Van Riper parcels are between 50 and 55 °F, close to the mean annual temperature of 49.7 °F recorded for Cedarville, Calif. (National Oceanic and Atmospheric Administration, 1974).

#### Oil and Gas

No oil and gas resources are identified. No surficial indications of oil and gas resources are present in the study area. No oil slicks on water, gas bubbles in water, or other visual evidence of hydrocarbons were noted (see Emmons, 1921). Traces (less than 0.5 weight percent) of hydrocarbons were extracted from some samples in the Granger, Milk, and Cottonwood parcels by solvent leaching (see Emmons, 1921, p. 28). Possible source beds for hydrocarbons include lignite beds reported in and near the study area by Russell (1928).

There are no oil and gas leases in the study area, and there has been no exploratory drilling for oil and gas in the study area. An exploratory geothermal well, 7,000 ft deep and located about 3.5 mi east of the Milk parcel (sec. 11, T. 41N., R. 16E.), showed no indications of oil and gas resources. Another drill hole, located 0.4 mi northeast of the Granger parcel (sec. 29, T. 42N., R. 16E.), likewise provided no evidence of oil and gas resources.

Traces of solvent-extractable hydrocarbons were detected in some rock samples, and organic-rich source rocks have been postulated to occur at depth in this region (Russell, 1928; Alldredge and Meigs, 1984). Should such source rocks exist, they would most likely be nonmarine in depositional environment and would generate natural gas but not oil. Scott (1983) considered the region including the study area to have low to zero potential for oil and gas.

#### Coal

Layers of lignite, mostly 1 in. or less thick, have been reported in a carbonaceous zone about 300 ft thick in the andesitic tuff breccias and conglomerates in or near the study area (Russell, 1928). Although some weakly carbonaceous tuff was observed in the north half of the study area during this study, no coal was identified. Lignite coal that reportedly occurs near the study area was considered no-economic by Russsell (1928). The few carbonaceous beds observed during this study are uneconomic occurrences.

## ASSESSMENT OF MINERAL RESOURCE POTENTIAL

*By* Michael G. Sawlan *and* James G. Frisken
*U.S. Geological Survey*

### Geology

The South Warner Contiguous Wilderness Study Area lies along the west margin of the Basin and Range province, an area characterized by north-trending ranges and intervening basins bounded by normal faults. The study area is underlain by Oligocene and Miocene volcanic rocks which form a gently west-dipping (20°–25°) homocline at least 10,000 ft thick. A variant in the structure occurs in the southern part of the study area in the Barber parcel where basalt and tuff dip to the east approximately 25°–35°. This area is separated from the west-dipping homocline by a fault. A generalized geologic map of the study area is shown in figure 2.

The homocline of the Warner Mountains is bounded on the east by the Surprise Valley fault zone. East of this fault zone, the Oligocene and Miocene strata have been downdropped at least 11,800 ft relative to strata in the Warner Mountains. Data from a drill hole in Surprise Valley indicate that these strata are buried by a minimum of 6,900 ft of alluvial and lacustrine deposits (Duffield and Fournier, 1974; Duffield and Weldin, 1976; Duffield and McKee, 1986).

#### Description of Stratigraphic Units

The Oligocene and Miocene strata are assigned to six units shown in figure 2. Some descriptive names of units are changed as noted. From oldest to youngest, these are: (1) andesitic volcaniclastic and sedimentary rocks (sedimentary rocks unit of Duffield and Weldin, 1976), (2) composite volcanic rocks, (3) basalt flows, (4) tephra , (5) mafic lava flows, and (6) rhyolite (volcanic rocks unit of Duffield and Weldin, 1976). These rocks range in age from about 34 to 14 Ma (million years) based on K-Ar ages reported by Duffield and McKee (1986). The andesitic volcaniclastic rocks unit is about 34 to 27 Ma in age. The composite volcanic rocks unit, which includes andesite lavas and ignimbrite, ranges in age from about 26 to 17 Ma. The four youngest units (basalt flows, mafic lava flows, tephra, and rhyolite) erupted in a relatively short time period, between 16 and 14 Ma.

##### Andesitic Volcaniclastic and Sedimentary Rocks

The oldest rocks in the study area are andesitic volcaniclastic rocks that underlie the five northernmost parcels (fig. 2). These rocks include andesite tuff breccia and conglomerate, subordinate sandstone, and minor andesite or green, pervasively fractured beds, typically 20–80 ft thick, of unsorted, angular andesite clasts in a matrix of lithic fragments and ash. Clasts in the tuff breccia are characteristically matrix-supported. Lithic fragments range in size from millimeters to several meters and are dominantly porphyritic pyroxene and hornblende andesite and aphyric basaltic andesite. Subordinate clast lithologies include subrounded ovoid clasts of hornblende and (or) biotite granodiorite, and plagioclase-rich basalt composed of large (as much as 0.4 in. across), densely crowded, aligned, tabular, plagioclase phenocrysts. The matrix of the tuff breccia is composed of comminuted lithic fragments, ash which is largely altered to clay, and broken phenocrysts. The tuff breccia commonly contains petrified or charred wood ranging from small twigs to logs several yards in length. The charred wood suggests that some tuff breccia formed as hot volcanic debris flows.

The andesitic tuff breccia is a rock type commonly attributed to lahars or mudflows deposited on the distal flanks of andesitic stratovolcanoes. Duffield and Fournier (1974) identified two vent complexes, 7 and 10 mi north of the study area, which may have been the source for some of the andesite volcaniclastic rocks. K-Ar ages on andesite from these eruptive centers are 26.6±1.1 Ma and 28.7±1.1 Ma, respectively (Duffield and McKee, 1986).

Conglomerate and sandstone contain clasts similar to those that occur in the andesitic tuff breccia; these rocks generally increase in proportion from south to north within the study area. In contrast to the tuff breccia, these clastic rocks are distinctly clast-supported. Hornblende-bearing andesite ash beds are a volumetrically minor constituent of this unit. Dates on andesite ash beds from three localities range from 28.8±1.0 Ma to 33.9±2.7 Ma (Duffield and McKee, 1986). The 34–29 Ma age range of andesite ash beds suggests that older sources for the andesite volcaniclastic rocks are required in addition to the younger (26.6 and 28.7 Ma) sources identified by Duffield and Fournier (1974).

### Composite Volcanic Rocks

The composite volcanic unit comprises late Oligocene and early Miocene rhyolite ignimbrite and andesite and dacite(?) lavas. This composite volcanic unit underlies the Eagle and parts of the Barber parcels. The rhyolite ignimbrite is typically white, partly welded, lithic-bearing, biotite-quartz-feldspar rhyolite ash-flow tuff with abundant flattened pumice lumps, typically 0.2–0.8 in. across. The lavas are dominantly gray and greenish-gray porphyritic andesite containing plagioclase, and pyroxene and (or) hornblende phenocrysts. At the Eagle parcel, the section includes ignimbrite which is underlain by andesite lava and overlain by thick (as much as 200 ft) andesite and dacite lava. Further south, in the Barber parcel, only the ignimbrite is exposed. The age range of this unit is bracketed by K-Ar ages on biotite from ignimbrites located stratigraphically below and above andesitic lavas. K-Ar ages of 25.4±1.0 and 26.3±1.0 Ma are reported for ignimbrite near the base of the unit; and an age of 17.3±0.6 Ma is reported for ignimbrite located near the top of this unit (Duffield and McKee, 1986). No K-Ar ages have been reported for the lavas from this unit.

### Basalt Flows

The basalt flows unit occurs in only the southermost parts of the study area, in the Emerson, Barber and Van Riper parcels. This unit includes black, typically vesicular and amygdaloidal, aphyric basalt and sparsely porphyritic olivine basalt. Vesicles are typically partially filled with zeolites. Basalt from the northeast part of the Emerson parcel has been dated at 15.8±0.5 Ma; six K-Ar ages on basalt from elsewhere in the South Warner Mountains range from about 16 to 14 Ma (Duffield and McKee, 1986).

### Tephra

The tephra unit occurs in spatial association with rhyolite lavas in the southern part of the study area, largely in the Barber parcel. This poorly exposed unit includes bedded rhyolitic lithic pumice tuff locally intercalated with basalt flows.

### Mafic Lava Flows

Mafic lava flows occur adjacent to the Van Riper Parcel in the southern part of the study area. This unit includes porphyritic basalt lava flows, 10–20 ft thick, and porphyritic andesite lava that typically forms massive to platy-jointed flows as much as 200 ft thick. No K-Ar ages are available for this unit.

### Rhyolite

The rhyolite unit occurs in the study area only in and around the Barber parcel. This unit includes flow-banded, locally hematite-stained, porphyritic biotite feldspar rhyolite flows. Rhyolite from within and adjacent to the Barber parcel is about 16 Ma old on the basis of K-Ar ages of 15.5±0.5 Ma and 15.9±0.5 Ma reported by Duffield and McKee (1986).

### Surficial Deposits

Two types of Quaternary surficial deposits are distinguished in the geologic map shown in figure 2: alluvium and gravel. In the study area, alluvium comprises unsorted to poorly sorted silt, sand and gravel. Farther east, this unit also includes lacustrine deposits, rare, thin tephra beds, and stream channel deposits. Gravels form deltaic fans deposited in large Surprise Valley lake(s) during high lake levels in Quaternary time. These deltaic fans are 0.5–2 mi across and 15–40 ft thick and are located along the east slope of the Warner Mountains adjacent to the Surprise Valley fault zone. Most of the gravel deposits occur outside of the study area; small parts of these deltaic fans are included in parts of the Eagle and Barber parcels. These gravels typically exhibit better sorting with a higher proportion of sand and gravel relative to silt than most alluvial fill in Surprise Valley.

### Intrusive Rocks

Dikes and sills of andesitic composition intrude tuff breccia and conglomerate of the andesitic volcaniclastic and sedimentary rocks unit, and ignimbrite and andesite lava flows of the composite volcanic unit. Dikes are locally abundant, particularly in the area west of Eagleville where a set of light gray, subvertical, generally east-trending dikes several hundred feet in height are exposed in the range-front scarp. The dikes include aphyric microcrystalline andesite as well as andesite with hornblende or pyroxene phenocrysts. These dikes are not shown on the generalized geologic map of figure 2.

### Structure

The most prominent structure in the study area is the Surprise Valley Fault zone, which has been active in the Pleistocene and Holocene (Hedel, 1980, 1981). This fault zone is marked by abundant geomorphic evidence of youth including the abrupt, steep, prominent range-front scarp, faceted spurs, perched stream terraces, small young alluvial cones, and offset surficial deposits within 2–3 mi of the main scarp. All parcels are located on the footwall (the relatively upthrown side of the fault) immediately west of the Surprise Valley fault zone. East of the Surprise Valley fault zone, this volcanic section is buried by at least 6,900 ft of alluvium in the Surprise Valley basin (Duffield and McKee, 1986). At least 11,800 ft of vertical offset is indicated along the Surprise Valley fault zone (Duffield and McKee, 1986). The age of the inception of faulting on the Surprise Valley fault zone is not well constrained.

In addition to the major north-northwest-trending basin and range faulting exemplified by the Surprise Valley fault, an earlier period of faulting is indicated by several major northeast-trending faults. These faults exhibit significant vertical displacement of Tertiary volcanic strata as young as 14 Ma (fig. 2) and are truncated by the Surprise Valley fault zone. The earliest age of activity on the northeast-trending faults is not known.

Tuff breccia of the andesitic volcaniclastic and sedimentary rock unit characteristically is pervasively fractured. North- and northeast-trending fracture sets, with a spacing of 2 to 12 in., are particularly common; their genesis and relation to mapped faults is unknown.

Oligocene and Miocene strata form a gently west-dipping (20°–25°) homocline throughout the Warner Mountains except in the southern part of the study area, in the Barber parcel, where basalt and tuff strata dip to the east approximately 25°–35°. This area is separated from the west-dipping homocline by a fault.

### Alteration and Mineralization

Two principal types of alteration and mineralization are observed in and adjacent to the study area. These include a weak epithermal gold mineralization and a regional alteration resulting in precipitation of zeolite, zeolite and calcite, calcite, or zeolite with minor grayish-brown chalcedony or milky white opal. Some calcite veining may be related to the epithermal mineralization. Both alteration types are strongly fracture controlled, resulting in planar alteration zones. The relative timing of the alteration types is not well constrained. At least some zeolite-related alteration post-dates the epithermal alteration, as evidenced by zeolites lining vugs in silicified rock, but earlier zeolite-related alteration cannot be ruled out. Epithermal mineralization and (or) alteration is observed in the Granger, Hornback, Eagle, and Barber parcels. In the following discussion on alteration, geochemical anomalies are noted; these geochemical data are more fully discussed in a later section.

Mineralized zones in the Granger Creek area, most of which are located north of the Granger parcel, are narrow (2- to 10-ft-wide), subvertical to steeply dipping, planar to broadly lensoidal, strongly silicified zones along north- and northeast-trending faults and (or) fractures. These zones cut gently west-dipping andesitic tuff breccia, and volcanic conglomerate and sandstone. Alteration zones range in length from several tens of feet to about 500 feet. Silicified zones are characterized by quartz veins and vein breccias and (or) dark reddish-brown to dark gray pervasively silicified volcaniclastic rock. The silicified areas may include sulfide and (or) limonite. The larger quartz veins range from white and pale yellowish-white, massive, thick (as much as 5 ft), finely crystalline quartz to translucent microcrystalline druse along fractures. Pervasively silicified rock ranges in color from gray to dark reddish-brown, depending on whether sulfides have been oxidized. These silicified zones characteristically form narrow ridges 2–8 ft high. The silicified zones may also include calcite, ferruginous calcite, and barite veins, and clay alteration dominated by kaolinite. Alteration envelopes adjacent to the strongly silicified zones are typically narrow, 3–10 ft wide. Broader alteration zones, as much as 50 ft wide, locally occur in volcanic sandstone and are characterized by rust-brown to reddish-brown limonite staining along fractures. Within the silicified zones, vugs and fractures may be lined with platy, crystalline, pale pink to colorless, translucent zeolite; zeolite also occurs outside of the zones related to silicification and, as noted above, may be unrelated to the silicification and mineralization.

Slickenslides generated by fault movement are observed along parts of some planar alteration zones. Fault displacements are difficult to define due to the absence of distinctive, continuous stratigraphic marker beds. Displacements along the silicified zones appear to be minor, however, as the major lithologic units are not offset significantly and the faults cannot be traced much beyond the silicified zones.

Rocks containing anomalous gold concentrations occur largely in the silicified zones. The higher gold anomalies most commonly are found in silicified rocks and vein breccia containing visible sulfide and (or) strong limonitic staining and boxwork after sulfide. Mineralized and altered rocks also yield geochemical anomalies, most notably of mercury, antimony, arsenic, molybdenum, copper, lead, silver, and cadmium. The maximum gold abundance in USGS rock samples collected from the mineralized area at Granger Creek is 64 ppb.

Volumes of gold-bearing rock are generally very limited because mineralization is strongly fracture controlled and does not extend significantly into the adjacent country rock. The volcaniclastic rocks appear to be an unfavorable host for replacement mineralization. Limonite-veined volcaniclastic rocks adjacent to the fracture-controlled alteration zones have anomalous concentrations of mercury, arsenic, and associated elements, possibly due to secondary remobilization, but only low levels of gold (≤5 ppb) were detected in these rocks.

Alteration observed in the central part of the Eagle parcel comprises a narrow (2- to 5-ft-wide), subvertical, northeast-trending, silicified, limonitic shear zone that forms a discontinuous (2- to 5-ft-high) ridge within ash-flow tuff. This area is located on the main northeast-trending ridge in the parcel (SW¹/₄, sec. 26, T. 40N., R. 16E.). This alteration zone locally exhibits fault slickenslides and can be traced for approximately 150–200 ft. A sample from this zone yielded anomalous concentrations of mercury, arsenic and lead. At the mouth of Eagle Creek, alteration occurs along a north-northwest-trending fracture zone or fault. Here, the alteration is characterized by minor quartz, chalcedony, and calcite veinlets, barite and zeolite in vugs, ochre-colored limonite, red hematitic and (or) cinnabar staining along fractures, and weak clay alteration of andesite lava. A sample of quartz and limonite-veined, partly clay altered andesite from this area contains anomalous concentrations of gold (9 ppb), as well as mercury and arsenic. About 0.15 mi southeast along strike from this altered area, fractured andesite containing minor calcite has anomalous concentrations of mercury and molybdenum.

In the Hornback parcel, sparse localized alteration has produced partial clay alteration of andesite, as well as thin (≤0.2 in.), finely crystalline quartz veinlets and abundant limonite-coated fractures within the andesite. Mercury and arsenic anomalies are associated with the limonitic fractures. Alteration was also noted in stream cobbles of altered tuff and chalcedony. The tuff is partly kaolinized and contains thin quartz veins, limonite, and small pockets of calcite. The chalcedony is gray and includes pervasive veinlets of yellow-brown limonite. Both the altered tuff and veined chalcedony have anomalous concentrations of mercury, arsenic, and molybdenum.

In the Barber parcel, vesicular basalt flows located in the northeast part of the parcel contain abundant zeolites in vugs. Fractured, locally iron-stained basalt lava contains anomalous concentrations of gold (7 ppb) and copper (200 ppm). Rhyolitic lithic pumice tuff exposed in a roadcut along the south margin of the parcel contains thin (≤0.4 in.), soft, brown clay-rich veins along fractures; these veins have anomalous concentrations of mercury and arsenic compared to the host tuff. Rhyolite lava and ignimbrite exposed in the northeast part of the parcel exhibit alteration or weathering of the glassy groundmass to green and yellow-white clays, respectively, but biotite and feldspar phenocrysts appear to be fresh. These rocks have relatively high concentrations of silver (10 ppm). Rhyolites are known elsewhere to contain similar concentrations of silver in unaltered rock. It is not clear whether the silver anomalies here are related to a widespread, subtle alteration or reflect relatively high magmatic silver concentrations. Minor silicification and clay alteration along slickenslides in faulted rhyolite ignimbrite were noted in the northeastern part of the parcel but yielded no geochemical anomalies. In the southeastern part of the parcel, a clay and chalcedony vein cutting pumice lapilli tuff show anomalous concentrations of gold (3 ppb), mercury (100 ppm), and arsenic (6 ppm); these veins did not appear to be common. Rhyolite lava in the southwest part of the Barber parcel is commonly stained with hematite along fractures, and locally contains pockets of silicification: two samples show minor gold anomalies (4 and 12 ppb).

Alteration at mercury prospect pits located about 2 mi north of Granger Creek, (between North Deep Creek and South Deep Creek) occurs along north- and northeast-trending fractures and (or) faults. Here, mercury mineralization is concentrated in dark reddish-brown, narrow, silicified zones, 2–6 ft wide, that locally contain barite veins and limonite. Adjacent country rocks are stained by limonite, hematite, and cinnabar along fractures, are locally altered to kaolinite, and have anomalous concentrations of mercury. Although samples from the Deep Creek area have high mercury concentrations (to 230 ppm), they are virtually devoid of gold; of the 12 samples from the prospect pits and nearby rocks, only one sample of green tuff contain detectable gold (2 ppb). Anomalous arsenic (≤42 ppm), antimony (≤24 ppm), boron (≤100 ppm), barium (>5,000 ppm), lead (≤70 ppm), molybdenum (≤10 ppm), and copper (≤150 ppm) are also observed in various samples from this area.

## Geochemical Studies

### Methods and Background

A reconnaissance geochemical study conducted by the USGS in and near the study area consisted of the collection, analysis, and evaluation of rock, stream-sediment, and heavy-mineral-concentrate samples.

The rock samples provide direct information on rock geochemistry. Samples that appeared fresh and unaltered were collected to provide information on geochemical background values, and those deemed altered or mineralized were collected to determine the suite of elements that characterize the alteration or mineralization. In all, 174 rocks were sampled from outcrops and an additional 10 rocks were collected as stream float.

The stream-sediment, and nonmagnetic heavy-mineral panned-concentrate samples (herein referred to as heavy-mineral concentrates) are collected primarily for their ability to reveal metal anomalies within drainage basins. Stream sediments represent a composite of rock and soil exposed upstream from the sample site. The processing of heavy-mineral concentrates tends to remove common rock-forming minerals and to concentrate ore and ore-related minerals. Analysis of this heavy-mineral concentrate provides data for some elements of interest that are not easily detected in bulk stream sediments. Twenty-five sites along stream channels containing recent alluvium were sampled for stream sediments. Heavy-mineral concentrates were obtained at 24 of these sites. Because of the small size of the parcels, the drainage basins from which the stream-sediment samples are derived in most instances extend beyond the surface area of the study area parcels into the adjacent South Warner Wilderness (within the Modoc National Forest). Less commonly, samples from small tributary drainages were derived from areas largely within the study area parcels. One water sample was collected from Van Riper Spring and analyzed for uranium (0.2 ppb).

Several analytical methods were employed, depending on the elements of interest. The rock, stream-sediment, and heavy-mineral-concentrate samples were analyzed for 31 elements (silver, arsenic, gold, barium, beryllium, bismuth, boron, cadmium, calcium, cobalt, chromium, copper, iron, lanthanum, magnesium, manganese, molybdenum, niobium, nickel, lead, scandium, antimony, tin, strontium, thorium, titanium, vanadium, tungsten, yttrium, zinc, and zirconium) by a six-step semiquantitative emission-spectroscopy method routinely used by the USGS (Grimes and Marranzino, 1968). Germanium, gallium, sodium, and phosphorus contents were also determined by this method on most of the rocks. Several elements of special interest were also analyzed by more sensitive techniques. Gold concentrations were determined in the rocks and stream sediments by a graphite furnace atomic-absorption method having a detection limit of 2 ppb (Meier, 1980). Gold analyses obtained by this method largely represent the gold introduced into the rock by mineralization and not the total gold concentrations in the rock; the common rock-forming silicates, which may contain trace amounts (<5 ppb) of gold, are not decomposed by the method used in gold analysis sample preparation. Mercury was detected by a cold vapor atomic-absorption method having a detection limit of 20 ppb (Koirtyohann and Khalil, 1976). Low-level antimony, arsenic, bismuth, cadmium, and zinc concentrations were determined by inductively coupled, argon-plasma atomic-emission spectroscopy (Crock and others, 1987). Detection limits for these elements are shown in parentheses as follows, in ppm units: antimony (2), arsenic (5), bismuth (2), cadmium (0.1), and zinc (2). In addition, the stream-sediment samples were analyzed for thorium and uranium by a delayed neutron technique (Millard, 1976). Anomalous values were determined by statistical methods, by comparison of mineralized and altered samples with their unaltered equivalents, and by comparison with published data for common rock types. Analytical data, sample-location maps, and a detailed description of the sampling and analytical techniques are presented by Adrian, B.M (written commun., 1988).

In addition to samples collected during the present study, the geochemical data from the study of the South Warner Wilderness (Duffield and Weldin, 1976) were examined. Data for 37 stream-sediment and 50 rock samples collected within or near the nine study area parcels were compiled and included in the present interpretations. These samples were analyzed by the same spectrographic method for 30 elements (as above less thorium), for gold with a detection limit of 50 ppb, and for mercury. During the 1976 study, the USBM collected nine reconnaissance placer samples from streams draining the east slope at the South Warner Mountains including Milk Creek, Steamboat Canyon, Cottonwood Creek, Jackson Canyon, Owl Creek, Raider Creek, Eagle Creek, Kaiser Canyon, and Emerson Creek. No gold was detected in these concentrates nor in any of the 24 heavy-mineral concentrates collected by the USGS during the present study. Only two low-level gold concentrations were found in the 553 rock samples and the 315 stream-sediment samples collected during the study of the entire South Warner Wilderness (Duffield and Weldin, 1976). It should be noted, however, that the analytical detection limit for gold in the present study is much lower lower than that of the 1976 study: 2 ppb versus 50 ppb.

### Results and Interpretation

Geochemical anomalies, alteration patterns, mineralogy, and some favorable geologic factors suggest that all nine parcels in the South Warner Contiguous Wilderness Study Area have been subjected to mineralizing processes similar to those that have produced epithermal precious-metal deposits elsewhere. The anomalous concentrations of elements form an element suite characteristic of present-day mineralized hot springs and related epithermal gold deposits. The geochemical data do not suggest the presence of mineral occurrences of types other than epithermal precious-metal mineralization. Anomalous concentrations of metals such as copper, molybdenum, lead, arsenic, antimony, and mercury, as well as some non-metals, are small and characteristic of a precious-metal geochemical association. In addition, no indications of occurrences of radioactive elements are present; sensitive analytical techniques used for detecting uranium failed to show any anomalous concentrations in the stream-sediment samples.

Anomalous concentrations of elements in samples from all three sample media (rocks, stream sediment, and heavy-mineral concentrates) occur throughout the study area. However, most of the multi-element anomalies and all of the pyrite ($FeS_2$), powellite ($CaMoO_4$) and barite ($BaSO_4$) seen in the heavy-mineral concentrates occur in samples collected from the six northern parcels (Granger, Milk, Cottonwood, Owl, Hornback, and Eagle parcels). In the stream sediments and heavy-mineral concentrates, the anomalous element suite consists, in part, of gold (5–17 ppb in stream sediment), silver (2–7 ppm in heavy-mineral concentrate), arsenic (5–10 ppm in stream sediment), antimony (3 ppm in stream sediment), molybdenum (10–700 ppm in heavy-mineral concentrate), copper (200–10,000 ppm in heavy-mineral concentrate), lead (100–1,500 ppm in heavy-mineral concentrate), tin (20–100 ppm in heavy-mineral concentrate), barium (5,000 to greater than 10,000 ppm in heavy-mineral concentrate), and boron (200 to greater than 5,000 ppm in heavy-mineral concentrate). Not all elements of this suite are present in all samples exhibiting anomalies; typically, anomalies of two to six elements are present in any particular sample.

Gold anomalies (2–17 ppb) were detected in 13 stream-sediment samples from the Granger (4 of 5 samples), Milk (1 of 2 samples), Cottonwood (2 of 2 samples), Hornback (3 of 4 samples), Barber (1 of 6 samples), and Van Riper (2 of 3 samples) parcels. The gold anomalies are less than 8 ppb except for one sample from the mouth of Hornback Creek (17 ppb). Compared to gold anomalies in stream-sediment samples taken near an active gold mine, gold anomalies in the study area are relatively small. Stream-sediment samples collected during the present study, taken adjacent to and about 1 mi downstream from the volcanic-hosted Hayden Hill gold mine, contain 2,200 and 50 ppb gold, respectively. Despite detection of gold in stream-sediment samples from the study area, heavy-mineral concentrates of these stream-sediment samples show no gold. This indicates that the gold is very fine grained and suggests that economic precious-metal deposits are not exposed at the surface and that gold placers are not present. Duffield and Weldin (1976) found no gold anomalies in stream-sediment samples from the South Warner Wilderness, but the sediment and rock samples collected for this earlier study were analyzed by a less sensitive method. Gold was not seen or detected in any of the heavy-mineral concentrates. This indicates that the gold is either very fine grained and (or) incorporated in silicate minerals, and that placer-gold deposits most likely do not exist in or near the study area. Although no heavy-mineral concentrate was obtained by the USGS for the Eagle parcel, a concentrate obtained by the USBM contained a trace of gold. Silver anomalies were identified in three heavy-mineral-concentrate samples from the Granger, Owl, and Cottonwood parcels.

Fifty-two of the 234 rock samples have detectable gold ranging in value from 2 to 65 ppb. Thirteen of these samples have gold values ≥5 ppb; nine of these are from the Granger Creek area, two are from the Eagle parcel, and one each is from the Hornback and Barber parcels.

Rock geochemical anomalies in the six northernmost parcels correspond with areas in which stream-sediment and heavy-mineral-concentrate anomalies are identified, and with the areas exhibiting alteration noted above. The composite geochemistry of mineralized rocks defines a geochemical-anomaly suite that includes gold (≤64 ppb), silver (<0.5 ppm), mercury (≤1.9 ppm), arsenic (≤670 ppm), antimony (≤12 ppm), barium (sometimes in excess of 5000 ppm), lead (≤ 50 ppm), molybdenum (20–100 ppm), and copper (100–500 ppm). Mineralized samples have multi-element anomalies, but, as with the stream-sediment samples, rock samples are not anomalous in all elements of the suite. Rocks containing the largest geochemical anomalies occur in or adjacent to alteration zones along north- and northeast-trending structures.

The higher gold, antimony, arsenic, and mercury concentrations in rocks are from the area located immediately north of the Granger parcel, on the south-facing slope north of Granger Creek. A small planar zone of silicification and kaolinization also occurs within the northeast tip of the Granger parcel where rock samples are weakly anomalous in gold (less than 10 ppb). In the Granger Creek area, all gold anomalies greater than 5 ppb occur in the silicified zones. Andesite tuff breccia and conglomerate wallrock collected adjacent to silicified zones characteristically contain only very low gold levels (≤5 ppb). Pod-shaped volumes of limonitic volcaniclastic rocks that abut silicified zones contain weakly anomalous concentrations of mercury, arsenic, or cadmium.

Volcanic sandstone from the Granger and Owl parcels has many limonite-stained fractures and contains anomalous concentrations of mercury, arsenic, cadmium, and molybdenum. In the Owl parcel, thin sandstone beds contain anomalous concentrations of these elements despite a lack of apparent alteration and geochemical anomalies in overlying and underlying rocks.

## Geophysical Studies

Geophysical evaluation of the mineral resources of the study area was based on interpretations of previously acquired aerial gamma-ray and aeromagnetic surveys. No new geophysical data were collected during the present study.

Regional aeromagnetic surveys were flown over the study area at a constant barometric elevation of 10,000 ft above sea level with east-west flightline spacings of about 1 mi (Duffield and Weldin, 1976). Along the east flank of the South Warner Mountains in the vicinity of the study area parcels, the magnetic contours define a gentle gradient with contours subparallel to the range front along the Surprise Valley fault zone. The magnetic data in this area result from the combined effects of the 5,000 ft decrease in elevation along the range front (increased distance to the magnetometer) and the lower magnetic susceptibility of the volcaniclastic rocks along the range front and the alluvium in Surprise Valley.

The airborne gamma-ray survey (Aero Service Division, 1981) was flown in east-west lines with a 6-mi spacing, and north-south lines with an 18-mi spacing, at a nominal terrain clearance of 400 ft. The radiometric spectra did not indicate any anomalous radioactivity in or near the study area.

Neither the aeromagnetic nor aerial radiometric data provide constraints on the distribution of mineralization in the study area. As noted above, areas exhibiting alteration related to gold mineralization are typically only 2–10 ft wide; these features are not resolved with geophysical data based on widely spaced flightlines.

## MINERAL AND ENERGY RESOURCE POTENTIAL

### Mineral Resources

The mineral resource potential of the South Warner Contiguous Wilderness Study Area was assessed on the basis of geologic investigations, geochemical and geophysical studies, and a study of prospects and claims in the area of reported mineral occurrences and deposits in the region. The entire study area is assigned a low potential for epithermal gold and silver resources, with a certainty level of C. This assignment is based on the widespread occurrence of alteration and geochemical anomalies associated with or directly indicating precious-metal mineralization.

Results of the present study show that geologic and (or) geochemical evidence of precious-metal epithermal alteration and mineralization is present throughout the study area. Mineralization is most pronounced in the Granger Creek area and was probably caused by the circulation of hydrothermal fluids enriched in gold, silver, mercury, arsenic, antimony, molybdenum, copper, lead, boron, barium, and cadmium through faults and fractures. The mineralized areas have alteration and geochemical attributes broadly similar to a Sado-type epithermal gold deposit characterized by fracture-controlled silicification in a volcanic host (Mosier and others, 1986).

Gold occurrences found to date are restricted to small volumes of rock along faults and fractures. The mapping and intensive rock sampling in the most favorable areas for gold indicate that gold deposits are not presently exposed in the study area. The lack of ore-grade gold concentrations in the study area may be explained in several ways. The mineralization may represent the base of ore bodies now largely removed by erosion, the uppermost expression of a deeper system, the periphery of ore bodies displaced by faulting, or a weak mineralization event.

Geochemical anomalies in base metals (copper, lead, and zinc) and other elements such as mercury, arsenic, antimony, and cadmium do not indicate potential resources for deposits of these elements. Concentrations of these elements are far below economic levels, and they are best viewed as accessory constituents of the element suite related to epithermal gold-related mineralization.

Although the present study indicates that gold deposits are unlikely to be found in the study area, additional geologic and alteration mapping and geochemical studies may provide information that could lead to identifying target areas in the general region. The objectives of this research should focus on establishing the timing of mineralization relative to development of pre- and post-mineralization structures and identifying favorable host rocks and structural traps.

### Geothermal Energy Resources

The Barber and Van Riper parcels have low potential for geothermal energy resources, certainty level C, on the basis of hot springs located 0.2 mi east of the study area (the Menlo Baths) and warm springs within the Barber and Van Riper parcels. These resources may be suitable for small-scale, low-temperature space heating. In the Lake City-Surprise Valley KGRA, which lies north and east of the study area, no geothermal leases or applications have been taken.

### Oil and Gas

Geologic data indicate the absence of oil and gas resources in or near the study area. Although organic-rich source rocks have been postulated to occur at depth in this region (Russell, 1928; Alldredge and Meigs, 1984, p. 83–87), they would most likely be nonmarine in origin and may possibly generate natural gas but not oil, if they exist at all. The Tertiary volcanic and volcaniclastic sequence contains only local, thin, and discontinuous layers of sedimentary rock that might act as hydrocarbon reservoirs. Rocks that underlie the study area are relatively impermeable as suggested by the apparent confinement of hydrothermal fluids to fractures and faults. There are no active oil and gas leases, no exploratory drilling, and no producing wells in the study area. Two drill holes located less than 1 mi northeast of the Granger parcel and about 3 mi east of the Milk parcel yielded no evidence of oil or gas resources.

In a previous assessment of oil and gas potential of wilderness lands, Scott (1983) considered this region to have zero to low potential. This report concurs with Scott's (1983) earlier finding and the study area is here considered to have no potential, certainty level D, for oil and gas resources.

## REFERENCES CITED


Aero Service Division, Western Geophysical Company of America, 1981, Airborne gamma-ray spectrometer and magnetometer survey, Alturas quadrangle, California: prepared for the U.S. Department of Energy as part of the National Uranium Resource Evaluation program under contract no. DE-AC13-76GJ01664 and Bendix Field Engineering Corporation subcontract no. 80-460, project no. IG0205, GJBX-406/81; final report v. 1, 127 p., and final report v. 2, unnumbered.

Alldredge, M.H., and Meigs, J.V., 1984, N.E. California area drawing interest: Oil and Gas Journal, v. 82, no. 23, p. 83–87.

American Society for Testing and Materials, 1985, Fly ash and raw or calcined natural pozzolan for use as a mineral admixture in portland cement concrete: 1985 annual book of ASTM Standards, part 10, section 4, construction; concrete and mineral aggregates: Philadelphia, Pennsylvania, American Society for Testing and Materials, designation C 618–85.

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

Crock, J.G., Briggs, P.H., Jackson, L.L, and Lichte, F.E., 1987, Analytical methods for the analysis of stream sediments and rocks from wilderness study areas: U.S. Geological Survey Open-File Report 87-84, 35 p.

Duffield W.A., and Fournier, R.O., 1974, Reconnaissance of the geothermal resources of Modoc County, California: U.S. Geological Survey Open-File Report, 19 p.

Duffield W.A., and McKee, E.H., 1986, Geochronology, structure, and basin-range tectonism of the Warner Range, northeastern California: Geological Society of America Bulletin, p. 142–146.

Duffield, W.A. and Weldin, R.D., 1976, Mineral resources of the South Warner Wilderness, Modoc County, California: U.S. Geological Survey Bulletin 1385–D, 31 p.

Emmons, W.H., 1921, Geology of petroleum: New York, McGraw-Hill, 610 p.

Gay, T.E., Jr., 1966, Economic mineral deposits of the Cascade Range, Modoc Plateau, and Great Basin region of northeastern California, *in* Bailey, E.H., ed., Geology of northern California: California Division of Mines and Geology, Bulletin 190, p. 97–104.

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.

Grimes, D.J., and Marranzino, A.P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.

Hedel, C.W., 1980, Late Quaternary faulting in western Surprise Valley, Modoc County, California: San Jose, California, California State University, M.S. thesis, 113 p.

Hedel, C.W., 1981, Map showing geothermal resources of the Lake City-Surprise Valley Known Geothermal Resource Area, Modoc County, California: U.S. Geological Survey Map MF–1299, scale 1:62,500.

Koirtyohann, S.R., and Khalil, Moheb, 1976, Variables in the determination of mercury by cold-vapor atomic absorption: Analytical Chemistry, v. 48, no. 1, p. 136–139.

Majmundar, H.H., 1983, Technical map of the geothermal resources of California: California Division of Mines and Geology, Geologic Data Map no. 5, scale 1: 750,000.

Majmundar, H.H., 1984, Text for the technical map of the geothermal resources of California geologic data map no. 5: California Division of Mines and Geology, 45 p.

McKelvey, V.E., 1972, Mineral resource estimates and public policy: American Scientist, v. 60, p. 32–40.

Meier, A.L., 1980, Flameless atomic absorption determination of gold in geologic material: Journal of Geochemical Exploration, v. 13, no. 1, p. 77–85.

Millard, H.T., Jr., 1976, Determination of uranium and thorium in U.S. Geological Survey standard rocks by the delayed neutron technique: U.S. Geological Survey Professional Paper 840, p. 61–65.

Miller, M.S., 1988, Mineral resources of the South Warner Contiguous Wilderness Study area, Modoc County, California: U.S. Bureau of Mines Minerals Land Assessment Open-File Report MLA 20–88.

Mosier, D.L, Berger, B.R., and Singer, D.A., 1986, Descriptive model of Sado epithermal veins, *in* Cox, D.P., and Singer D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p 155–157.

National Oceanic and Atmospheric Administration, 1974, Climates of the states, vol. 2, western states including Alaska and Hawaii: Port Washington, N.Y., Water Information Center, Inc., p. 481–975.

Russell, R.J., 1928, Basin and Range structure and stratigraphy of the Warner Range, northeastern California: University of California Publications in Geological Sciences, v. 17, no. 11, p. 387–496.

Scott, E.W., 1983, Petroleum potential of wilderness lands in California, *in* Miller, B.M., ed., Petroleum potential of wilderness lands in the western United States: U.S. Geological Survey Circular 902–A–P, p. D1–D12.

Slosson, J.E., 1974, Surprise Valley Fault: California Division of Mines and Geology, California Geology, v. 27, p. 267–270.

Tunnel, George, 1972, Mercury, *in* Wedepohl, K.H., ed., Handbook of Geochemistry, Berlin, Springer-Verlag, v. 2, chapter 80, p. F3–20.

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

Woods, M.C.,1974, Geothermal activity in Surprise Valley: California Division of Mines and Geology, California Geology, v. 27, p. 271–273.

# 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 | H/B HIGH POTENTIAL | H/C HIGH POTENTIAL | H/D HIGH POTENTIAL |
| | M/B MODERATE POTENTIAL | M/C MODERATE POTENTIAL | M/D MODERATE POTENTIAL |
| UNKNOWN POTENTIAL | L/B LOW POTENTIAL | L/C LOW POTENTIAL | L/D LOW POTENTIAL |
| | | | N/D NO POTENTIAL |

LEVEL OF CERTAINTY →

Abstracted with minor modifications from:


Taylor, R.B., and Steven, T.A., 1983, Definition of mineral resource potential: Economic Geology, v. 78, no. 6, p. 1268-1270.
Taylor, R.B., Stoneman, R.J., and Marsh, S.P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40-42.
Goudarzi, G.H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84-0787, p. 7, 8.

## RESOURCE/RESERVE CLASSIFICATION

| | IDENTIFIED RESOURCES | | | UNDISCOVERED RESOURCES | |
|---|---|---|---|---|---|
| | Demonstrated | | 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<br>Middle<br>Early | 205 |
| | | Triassic | | Late<br>Middle<br>Early | ~240 |
| | Paleozoic | Permian | | Late<br>Early | 290 |
| | | Carboniferous Periods | Pennsylvanian | Late<br>Middle<br>Early | ~330 |
| | | | Mississippian | Late<br>Early | 360 |
| | | Devonian | | Late<br>Middle<br>Early | 410 |
| | | Silurian | | Late<br>Middle<br>Early | 435 |
| | | Ordovician | | Late<br>Middle<br>Early | 500 |
| | | Cambrian | | Late<br>Middle<br>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.

# Mineral Resources of Wilderness Study Areas: Northeastern California and Part of Adjacent Washoe County, Nevada

This volume was published as separate chapters A–F

U.S. GEOLOGICAL SURVEY BULLETIN 1706

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, Jr., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

# CONTENTS

[Letters designate the separately published chapters]

# SELECTED SERIES OF U.S. GEOLOGICAL SURVEY PUBLICATIONS

## Periodicals

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

## Technical Books and Reports

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

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

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

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

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

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

## Maps

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

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

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

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

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

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

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

## Catalogs

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

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

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

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

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

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

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

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

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

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849