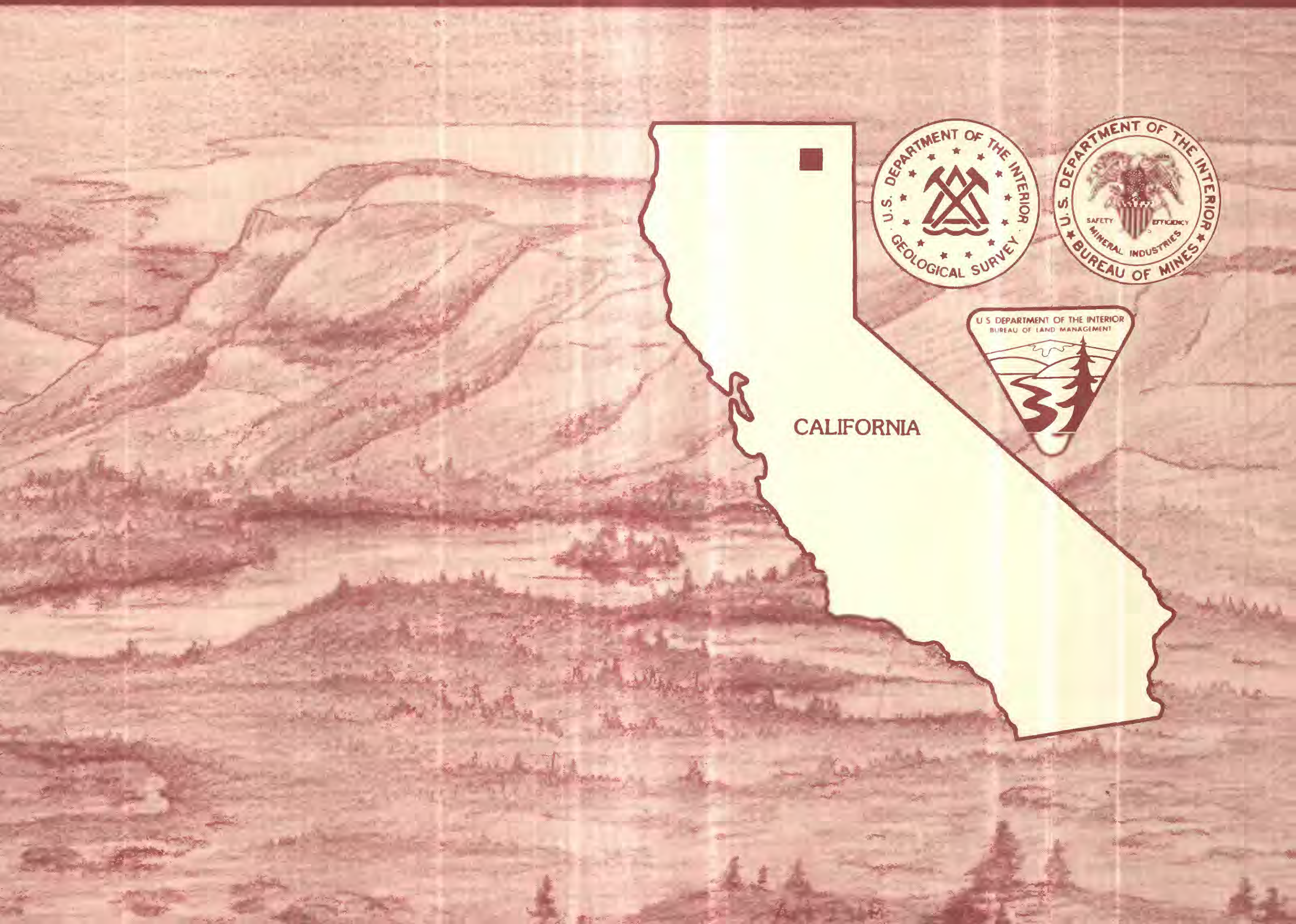
# Mineral Resources of the Tunnison Mountain Wilderness Study Area, Lassen County, California

U.S. GEOLOGICAL SURVEY BULLETIN 1706–B



Chapter B

# Mineral Resources of the Tunnison Mountain Wilderness Study Area, Lassen County, California

By JOCELYN A. PETERSON, JAMES G. FRISKEN, DONALD PLOUFF, and CAROLYN A. GOELDNER
U.S. Geological Survey

STEVEN R. MUNTS
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
DONALD PAUL HODEL, Secretary

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

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1988

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**

Mineral resources of the Tunnison Mountain Wilderness
Study Area, Lassen County,California.

U.S. Geological Survey Bulletin 1706-B
Bibliography
Supt. of Docs. No.: I 19.3:1706-B
1. Mines and mineral resources—California—Tunnison
Mountain Wilderness. 2. Tunnison Mountain Wilderness
(Calif.) I. Peterson, Jocelyn A. II. Series. III. Series: U.S.
Geological Survey Bulletin 1706-B.

QE75.B9 No. 1706-B 557.3 s 87-600424
[TN24.C2] [553'.09794'26]

## STUDIES RELATED TO WILDERNESS

### Bureau of Land Management Wilderness Study Area

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of part of the Tunnison Mountain Wilderness Study Area (CA-020-311), Lassen County, California.

## CONTENTS


Summary **B1**
- Abstract **1**
- Character and setting 1
- Identified resources and mineral resource potential **1**

Introduction **1**
- Acknowledgments **2**

Appraisal of identified resources **2**

Assessment of mineral resource potential **3**
- Geology **3**
- Geochemistry **3**
- Geophysics **5**
- Mineral and energy resources **5**

References cited **5**

Appendixes
- Definition of levels of mineral resource potential and certainty of assessment **9**
- Resource/reserve classification **10**
- Geologic time chart **11**


## FIGURES


1. Index map showing location of the Tunnison Mountain Wilderness Study Area, Lassen County, California **B2**
2. Map showing mineral resource potential and generalized geology of the Tunnison Mountain Wilderness Study Area, Lassen County, California **4**

# Mineral Resources of the Tunnison Mountain Wilderness Study Area, Lassen County, California

*By* Jocelyn A. Peterson, James G. Frisken, Donald Plouff, *and* Carolyn A. Goeldner
*U.S. Geological Survey*

Steven R. Munts
*U.S. Bureau of Mines*

## SUMMARY

### Abstract

The part of the Tunnison Mountain Wilderness Study Area (CA-020-311) requested for mineral surveys encompasses 8,445 acres in northeastern California. Field work was carried out during the summer of 1985 by the U.S. Bureau of Mines and the U.S. Geological Survey to assess the known mineral resources and the mineral resource potential (undiscovered) of the study area. The area has no identified resources. Geothermal areas south and southwest of the study area suggest that the area may have potential for geothermal energy resources; therefore, it has been assigned low potential for such resources. Building and construction stone and sand and gravel are present in the area but are too far from existing markets and in quantities too small to constitute resources. There is no evidence for potential for other commodities such as metallic minerals and oil and gas. Throughout this report, reference to the Tunnison Mountain Wilderness Study Area or the study area refers only to that part of the wilderness study area requested for mineral surveys by the U.S. Bureau of Land Management.

### Character and Setting

The Tunnison Mountain Wilderness Study Area (CA-020-311) is located in northeastern California about 10 mi northeast of Susanville (fig. 1). The area is characterized by an arcuate series of closely spaced, rounded peaks, the flanks of which descend into river valleys. A sequence of intermediate-composition pyroclastic rocks underlies the area. Overlying this is a series of basaltic andesite lava flows. The southern part of the area is covered by a young basalt erupted from a shield volcano east of the area. Isolated outcrops of ash-flow tuff overlie the basalt and protrude through alluvium.

### Identified Resources and Mineral Resource Potential

There are no identified resources within the study area; small amounts of building and construction stone and sand and gravel are present, although in insufficient quantities and too far from existing markets to constitute resources.

Several localities southwest and south of the study area, near Susanville and Honey Lake (15 mi south), have hot- and warm-water wells that are being exploited or evaluated by government and industry. The study area has a low potential for geothermal energy (fig. 2); the geologic terrane of the study area is somewhat different from that at known wells, and springs in the study area issue cold water and show no visible evidence of hydrothermal activity. The study area is characterized primarily by a mountainous terrain, which may not contain appropriate reservoir rocks.

There is no evidence for potential for metallic minerals or oil and gas.

## INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management (BLM) and is a joint effort by the U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (USBM). An introduction to the wilderness review process, mineral survey methods, and agency responsibilities was provided by Beikman and others (1983). The USBM 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 described by U.S. Bureau of Mines and U.S. Geological Survey (1980). Studies by the USGS are designed to provide a reasonable scientific basis for assessing the potential for undiscovered mineral resources by determining geologic units and structures, possible environments of mineral deposition, presence of geochemical and geophysical anomalies, and applicable ore-deposit models. Mineral assessment methodology and terminology as they apply to these surveys were discussed by Goudarzi (1984). See appendix for the definition of levels of mineral resource potential, certainty of assessment, and classification of identified resources.

The Tunnison Mountain Wilderness Study Area (CA-020-311) covers 8,445 acres in northeastern California (fig. 1) at the southwest edge of the Modoc Plateau physiographic province, a transitional area between the Basin and Range and Cascade Range geologic provinces. The area includes the rounded peaks that form Tunnison Mountain. Elevations in the area range from greater than 6,000 ft at the top of Tunnison Mountain to about 4,500 ft in the valley to the east. A few springs are present along the north boundary and Willow Creek is a perennial stream. Annual precipitation of approximately 10 in. allows the growth of sagebrush and grasses on slopes, ponderosa pine at low elevations, and some mountain mahogany along the ridge crest. An unimproved dirt road provides access to the north half of the area. Roads do not cross Willow Creek in the south and the easiest access to the south half of the area is by foot over the ridge crest from the north.

The USGS mapped the geology of the study area during two weeks in the summer of 1985 (Peterson and Goeldner, 1987) and collected rock and stream-sediment samples for geochemical analyses. Reconnaissance maps by Lydon and others (1960) and the California Division of Water Resources (1963) describe the regional geology. A report by Roberts (1985) describes the geology of the area between Honey Lake and the study area.

The USBM searched published literature, county claim records, USBM Mineral Industry Location System records, and BLM mining and mineral lease records. Also, information from USBM, state, and other production records was used. Field work included a search for mines, prospects, and mining claims within and adjacent to the study area and sampling of rocks and stream sediments for geochemical analyses.


**Acknowledgments**

Personnel at the BLM offices in Susanville provided information about the area and about access to it. They also provided office space for map compilation. J.L. Jones, T.A. Delaney, and John Mariano assisted with the field work.


## APPRAISAL OF IDENTIFIED RESOURCES

By Steven R. Munts
U.S. Bureau of Mines

Lassen County claim records indicate that no lode or placer mining claims have been located in or within 5 mi of the Tunnison Mountain Wilderness Study Area. According to 1985 BLM records, there are no mining claims or oil and gas leases within the study area.

Thirty-two sites were sampled during this study, 29 inside the study area and three outside (Munts, 1987). On the basis of chemical analyses of samples and site examination, no metallic resources were found (Munts, 1987). Although samples analyzed by one method have higher than expected concentrations of several elements, there may be distortions from interelement interference in these samples.

One alluvial sample collected outside the study area near Petes Creek contained subrounded, approximately 400-mesh-size gold particles, which may indicate a relatively distant source. The alluvium had a gold value of $0.06/yd$^3$ (at a gold price of $400.00/troy oz). This site contains less than 100 yd$^3$ of gravel; because of the low grade and small volume, this alluvium does not constitute a resource. However, the gold implies an upstream source, which may be related to faulting, the presence of rhyolite, or volcanic activity.

Nonmetallic commodities in the study area include sand and gravel, building stone, and construction stone. Sand and gravel occurrences are

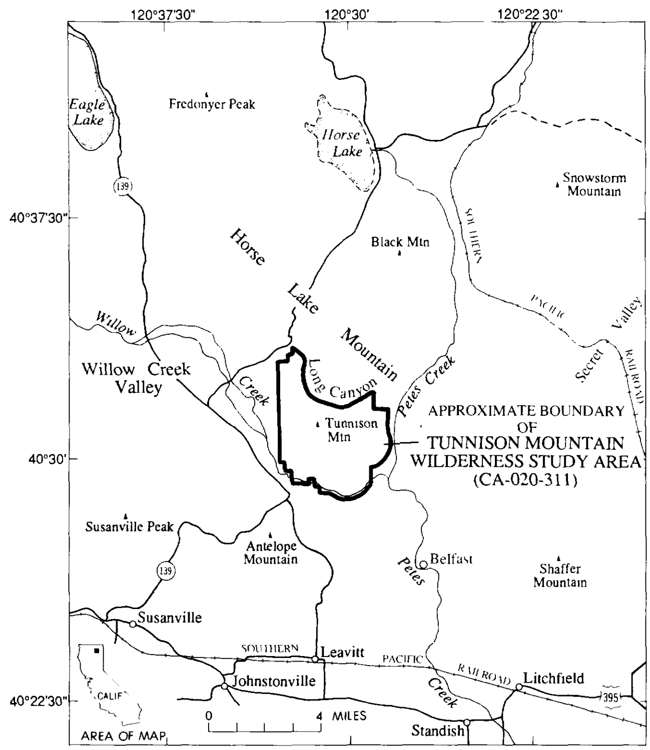



**Figure 1.** Index map showing location of the Tunnison Mountain Wilderness Study Area, Lassen County, California.

not resources because of small volumes and lack of local markets. A small area in the SE 1/4 NW 1/4 sec. 26, T. 31 N., R. 13 E., near Petes Creek, contains flaggy basaltic andesite composed of 4- to 6-in.-thick slabs useful for ornamental building stone. Some of the study area is covered by basaltic andesite of sufficient quality for commercial construction uses and scoria and pumice exposed in Long Canyon is of sufficient quality to be used for some specific construction or decorative purposes. However, none of these rock types constitute a resource because of poor access and insufficient quantity.

## ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Jocelyn A. Peterson, James G. Frisken, Donald Plouff, and Carolyn A. Goeldner
U.S. Geological Survey

### Geology

The Tunnison Mountain Wilderness Study Area, like most of the Modoc Plateau, is underlain by Miocene to Holocene (see appendix for geologic time chart) Cascade-related volcanic rocks (Grose and McKee, 1982). At Tunnison Mountain, intermediate-composition pyroclastic rocks and basaltic andesite lava flows form the mountain, whereas younger basalt and Quaternary colluvium and alluvium cover adjacent low areas (fig. 2).

The oldest exposed rocks in the study area are members of a Miocene (J.G. Smith, written commun., 1986) pyroclastic sequence. Most of the pyroclastic rocks are crystal-lithic tuff containing mafic to intermediate lithic clasts and plagioclase, pyroxene, and rare olivine crystals in a glassy matrix. A thin, apparently discontinuous, silicic, nonwelded ash-flow tuff containing pumice fragments, lithic clasts, and crystals of plagioclase, orthoclase, quartz, and biotite in a matrix of glass shards forms the top of the pyroclastic sequence. A welded tuff, occupying an uncertain stratigraphic position within the pyroclastic sequence, contains lithic fragments, fiamme (very stretched pumice), and sparse crystal fragments in a devitrified glassy matrix that has feldspar microlites.

About 1,300 ft of Miocene basaltic andesite lava flows overlie the pyroclastic sequence and cover most of the study area. Because this unit forms the bulk of Tunnison Mountain, it is informally called the basaltic andesite of Tunnison Mountain. The unit consists of three mineralogically and texturally distinctive flows and a feeder vent. Also, a cinder cone exposed in Long Canyon is tentatively correlated with the basaltic andesite flows. The flows and vent rocks contain varying amounts of plagioclase, olivine, clinopyroxene, and orthopyroxene phenocrysts in a groundmass of plagioclase, pyroxene, some olivine, and opaque-oxide minerals. Flow banding is a prominent feature of the middle lava flow. Rocks from the cinder cone contain a few olivine and plagioclase phenocrysts in an oxidized glassy groundmass.

In the southern part of the study area, basalt that flowed west from a shield volcano to the east occupies part of the Willow Creek drainage and valley. The basalt is here informally called the basalt of Willow Creek. Its distinctive, finely porous or diktytaxitic texture, general lack of phenocrysts, and massive outcrops distinguish it from the basaltic andesite of Tunnison Mountain. The basalt contains plagioclase, intergranular clinopyroxene or orthopyroxene, olivine, and opaque-oxide minerals. A sample collected near Belfast (fig. 1) yielded a whole-rock potassium-argon age of 4.9±1.4 Ma (Roberts, 1985), giving this unit a Pliocene age.

Isolated outcrops of ash-flow tuff locally overlie the basalt of Willow Creek and protrude through alluvium in Willow Creek Valley. The tuff contains pumice fragments, lithic clasts, and crystals in a matrix of glass shards. Textural differences suggest that there may be two ash flows, but there is no stratigraphic means of distinguishing them and the available chemical data are insufficient to make a distinction.

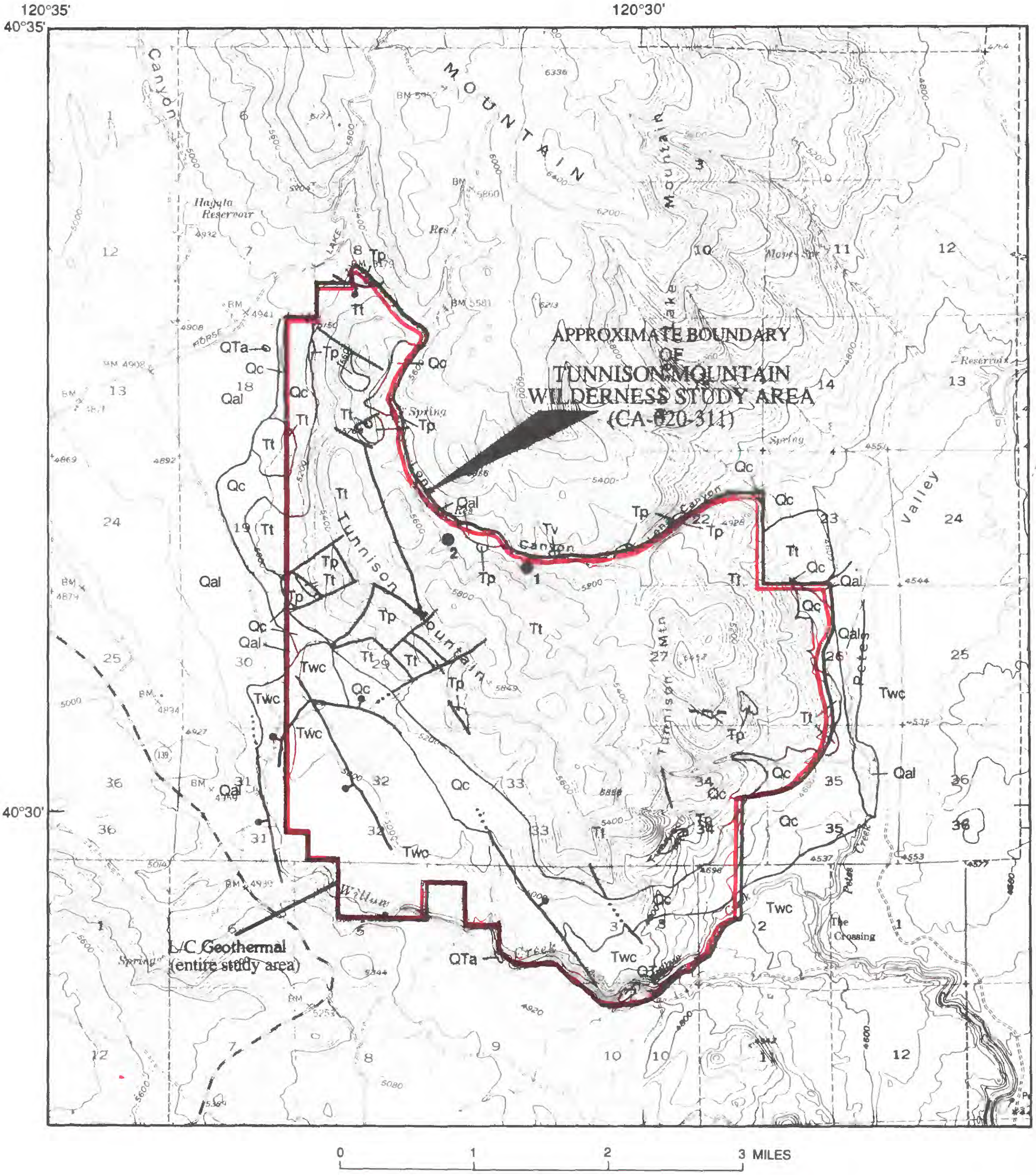
The west and south sides of Tunnison Mountain were faulted by high-angle normal faults, possibly of two ages. Faults strike both northeast and northwest resulting in several offsets of the volcanic sequence. The basaltic andesite of Tunnison Mountain was also tilted slightly to the northeast. The younger faulting has offset the basalt of Willow Creek (fig. 2).

### Geochemistry

The reconnaissance geochemical study of the Tunnison Mountain Wilderness Study Area is based on 33 rock samples collected from 33 outcrops, three stream cobbles collected at two sites, and 13 samples each of minus-80-mesh stream sediments and nonmagnetic concentrates panned from recent stream sediments collected from 13 dry stream beds. Most of the sediment samples represent drainage basins covering less than 1 $mi^2$. The samples were ground and analyzed for 31 elements by emission spectrography (Grimes and Marranzino, 1968). Rock samples also were analyzed by atomic absorption (Viets, 1978) for arsenic, bismuth, cadmium, antimony, and zinc, and stream cobbles were further analyzed for mercury (McNerney and others, 1972; Vaughn and McCarthy, 1964). Both rock and cobble samples were analyzed to characterize the geochemical nature of the predominantly mafic bedrock of the study area. The stream sediments were also analyzed for mercury and uranium (Centanni and others, 1956). A split of each panned concentrate was examined microscopically.

Unmineralized rock samples and minus-80-mesh stream sediments typically represent the geochemistry of the exposed bedrock of an area, although widespread pervasive or nearby isolated mineral occurrences may produce geochemical anomalies in these kinds of samples. The nonmagnetic concentrates, on the other hand, exclude most rock-forming minerals and concentrate many minerals related to mineralization and hydrothermal alteration.

In the Tunnison Mountain Wilderness Study Area, the geochemical data from all sample media have values characteristic of unmineralized mafic volcanic rocks. The sample from location 1 (fig. 2), representing a small drainage basin near Long Canyon,




## EXPLANATION

| | | | |
|---|---|---|---|
| (red outline) | Area with low geothermal resource potential--Applies to entire study area. See appendix for definition of levels of mineral resource potential and certainty of assessment | QTa | Ash-flow tuff (Quaternary or Tertiary) |
| | | Twc | Basalt of Willow Creek (Pliocene) |
| | | Tt | Basaltic andesite of Tunnison Mountain (Miocene) |
| | | Tv | Volcanic cinder deposits (Mioccene) |
| | | Tp | Pyroclasitc rocks (Miocene) |
| | Geologic map units | —— | Contact |
| | | (fault symbol) | Fault—Dashed where approximate, dotted where concealed; bar and ball on downthrown side. |
| Qal | Alluvium (Quaternary) | | |
| Qc | Colluvium (Quaternary) | ●2 | Geochemical sample-collection site—Numbers refer to text |

**Figure 2.** Mineral resource potential and generalized geology of the Tunnison Mountain Wilderness Study Area, Lassen County, California.

has 100 parts per million (ppm) lead in the concentrate, but no other anomalous elements. This value is perhaps marginally anomalous, although it could result from lead shot used by hunters. No pyrite, barite, or other minerals associated with known ore deposits in the region were noted in the microscopic study of the concentrates. Scattered low-level concentrations of bismuth (2-4 ppm), cadmium (2.3-2.4 ppm), strontium (2,000 ppm), and (or) barium (3,000 ppm) are present in several rock and cobble samples, predominantly in the southeast third of the study area. These concentrations are perhaps slightly anomalous and are probably insignificant.

Only one concentrate contained visible minerals possibly related to mineralization. That concentrate, from a small drainage basin west of Long Canyon (fig. 2, sample location 2), contained a single visible grain of gold, but the spectrographic analysis of the sample showed no anomalous gold concentrations. In a resampling of the area in 1986, no gold was detected visually in a panned concentrate and none was detected in an analysis of a composite sample of rock cobbles.

### Geophysics

Geophysical evaluation of the study area was based on interpretations of aerial gamma-ray, aeromagnetic, and gravity data.

Aerial gamma-ray (radiometric) data were compiled by Western Geophysical Company of America (1981) for the National Uranium Resource Evaluation (NURE) program of the U.S. Department of Energy. The coverage over the study area consists of a 1-mi-long segment of an east-west flightline located about 1 mi south of the northernmost point of the study area and a 3-mi-long segment of a north-south flightline located about 0.5 mi west of the east boundary of the study area. Flight altitudes ranged from 350 to 450 ft above the ground. Recordings were made of gamma-ray flux from radioactive isotopes of uranium, thorium, and potassium. Count rates of two standard deviations above mean background level were recorded for each of the three isotopes near the center of the study area along the east flank of the mountains. No anomalies were noted inside the study area along the east-west flightline, but count rates of about one standard deviation above mean background level were indicated adjacent to the study area to the east. The radioactive element anomalies probably do not indicate a mineralized area. Aeromagnetic intensities recorded along the same flightlines showed no conspicuous magnetic anomalies.

In 1985, five gravity stations were established in and near the study area to supplement values recorded at 26 other gravity stations (Snyder and others, 1982) within 5 mi of the study area boundary. The most conspicuous anomaly on a preliminary Bouger gravity anomaly map derived from these data (Donald Plouff, unpub. data, 1986) is a gravity high centered less than 0.5 mi east of the east edge of the study area. That anomaly has an amplitude of about 5 milligals (mGal) and a diameter of about 5 mi. Gravity values decrease an additional 5 mGal northwesterly toward the north corner of the study area. The source of the gravity high may be an underlying igneous intrusion located east of the study area and associated with the shield volcano that erupted the basalt of Willow Creek.

### Mineral and Energy Resources

The Tunnison Mountain Wilderness Study Area has a low potential for geothermal resources with a certainty of C (fig. 2). Warm- and hot-water wells are found in several localities within 15 mi of the study area. Wells near Susanville have temperatures between 80 and 147 °F (Bliss, 1983; Reed and others, 1983) and have been considered for use in heating buildings (Higgins, 1980). Wells and springs northeast of Honey Lake, 15 mi south of the study area, are part of the Wendell-Amedee geothermal area. Water from this area has temperatures between 189 and 225 °F (Bliss, 1983; Reed and others, 1983) and is used to heat greenhouses (Higgins, 1980). Two springs at the north end of Secret Valley east of the study area have temperatures of 70 and 72 °F (Bliss, 1983; Reed and others, 1983). Because of these nearby warm-water wells and springs, the Tunnison Mountain study area has low potential for geothermal energy. Several factors, however, lessen the likelihood that the area contains warm water at depth. First, several springs issuing into Long Canyon are not warm-water springs. Second, the known warm-water springs and wells occur in valleys, not in the mountains, where appropriate reservoir rocks are less likely. Third, the study area lies 10 mi north of most of the known thermal wells.

Scott (1983) assigned the Tunnison Mountain Wilderness Study Area a "low to zero" potential for oil and gas. We concur with Scott.

Weak geochemical anomalies and the lack of suitable host rocks, local tectonic structures, veins, or visibly altered bedrock all suggest that metallic mineral deposits are absent in the Tunnison Mountain Wilderness Study Area.

## REFERENCES CITED


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.

Bliss, J.D., 1983, California--Basic data for thermal springs and wells as recorded in GEOTHERM, Part A: U.S. Geological Survey Open-File Report 83-428A, 108 p.

California Divison of Water Resources, 1963, Northeastern counties ground water investigations: California Division of Water Resources Bulletin 98, 224 p.

Centanni, F.A., Ross, A.M., and DeSesa, M.A., 1956, Fluorimetric determination of uranium: Analytical Chemistry, v. 28, p. 1651.

Goudarzi, G.H., 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84-878, 42 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.

Grose, L.T., and McKee, E.H., 1982, Late Cenozoic westward volcanic progression east of Lassen Peak, northeastern California abs. : EOS, Transactions of the American Geophysical Union, v. 63, no. 45, p. 1149.

Higgins, C.T., 1980, Geothermal resources of California: California Division of Mines and Geology, California Geologic Data Map Series, Map No. 4, scale 1:750,000.

Lydon, P.A., Gay, T.E., Jr., and Jennings, C.W., 1960, Geologic map of California, Westwood sheet (Susanville): California Division of Mines and geology, scale 1:250,000.

McNerny, J.J., Buseck, P.R., and Hanson, R.C., 1972, Mercury detection by means of thin gold films: Science, v. 178, p. 611-612.

Munts, S.R., 1987, Mineral resources of the Tunnison Mountain study area, Lassen County, California: U.S. Bureau of Mines MLA Report 32-87, 18 p.

Peterson, J.A., and Goeldner, C.A., 1987, Geologic map of the Tunnison Mountain Wilderness Study Area, Lassen County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1945, scale 1:62,500.

Reed, M.J., Mariner, R.H., Brook, C.A., and Sorey, M.L., 1983, Selected data for low temperature (less than 90 °C) geothermal systems in the United States: reference data for U.S. Geological Survey Circular 892: U.S. Geological Survey Open-File Report 83-250, 129 p.

Roberts, C.T., 1985, Cenozoic evolution of the northwestern Honey Lake Basin, Lassen County, California: Colorado School of Mines Quarterly, v. 80, no. 1, 64 p.

Scott, E.W., 1983, Petroleum potential of wilderness lands, California: U.S. Geological Survey Miscellaneous Investigation Series Map I-1538, scale 1:1,000,000.

Snyder, D.B., Roberts, C.W., Saltus, R.W., and Sikora, R.F., 1982, Magnetic tape containing the principal facts of 64,026 gravity stations in the state of California: National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161, PB-82-168279, description, 30 p., PB-82-168287, magnetic tape.

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.

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.

Vaughn, W.W., and McCarthy, J.H., Jr., 1964, An instrumental technique for the determination of submicrogram concentrations of mercury in soils, rocks, and gas, in U.S. Geological Survey Journal of Research 1964: U.S. Geological Survey Professional Paper 501-D, p. D123-D127.

Viets, J.G., 1978, Determination of silver, bismuth, cadmium, copper, lead, and zinc in geologic materials by atomic absorption spectrometry with tricaprylylmethylamonium chloride: Analytical Chemistry, v. 50, p. 1097-1101.

Western Geophysical Company of America, 1981, National gamma-ray spectrometer and magnetometer survey, Susanville quadrangle, California--Final report: U.S. Department of Energy Open-File Report GJBX-410 (81), v. 2, 95 p., scale 1:500,000.

# APPENDIXES

# DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

## Definitions of Mineral Resource Potential

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

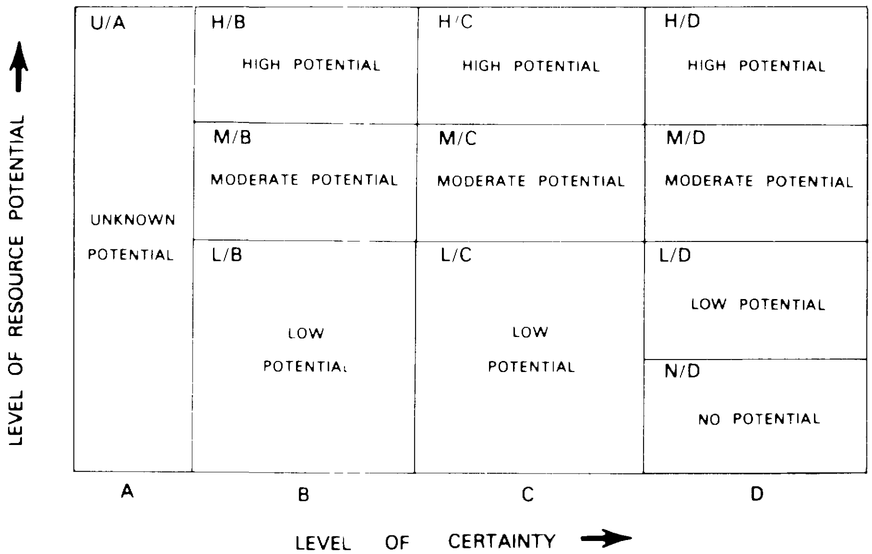
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate reasonable likelihood of resource accumulation, and (or) where an application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

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

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

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

## Levels of Certainty




A. Available information is not adequate for determination of the level of mineral resource potential.

B. Available information suggests the level of mineral resource potential

C Available information gives a good indication of the level of mineral resource potential

D. Available information clearly defines the level of mineral resource potential

## Abstracted with minor modifications from:


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

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

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

# RESOURCE/RESERVE CLASSIFICATION

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

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

# GEOLOGIC TIME CHART

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

| EON | ERA | PERIOD | | EPOCH | AGE ESTIMATES OF BOUNDARIES (in Ma) |
|---|---|---|---|---|---|
| Phanerozoic | Cenozoic | Quaternary | | Holocene | 0.010 |
| | | | | Pleistocene | 1.7 |
| | | Tertiary | Neogene Subperiod | Pliocene | 5 |
| | | | | Miocene | 24 |
| | | | Paleogene Subperiod | Oligocene | 38 |
| | | | | Eocene | 55 |
| | | | | Paleocene | 66 |
| | Mesozoic | Cretaceous | | Late | 96 |
| | | | | Early | 138 |
| | | Jurassic | | Late<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 | ~570[1] |
| Proterozoic | Late Proterozoic | | | | 900 |
| | Middle Proterozoic | | | | 1600 |
| | Early Proterozoic | | | | 2500 |
| Archean | Late Archean | | | | 3000 |
| | Middle Archean | | | | 3400 |
| | Early Archean | | | | |
| | | - (3800 ?) - | | | |
| pre-Archean[2] | | | | | 4550 |

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

[2]Informal time term without specific rank.

GPO 585-045/78028

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