Mineral Resources of the Twin Peaks Wilderness Study Area, Washoe County, Nevada, and Lassen County, California

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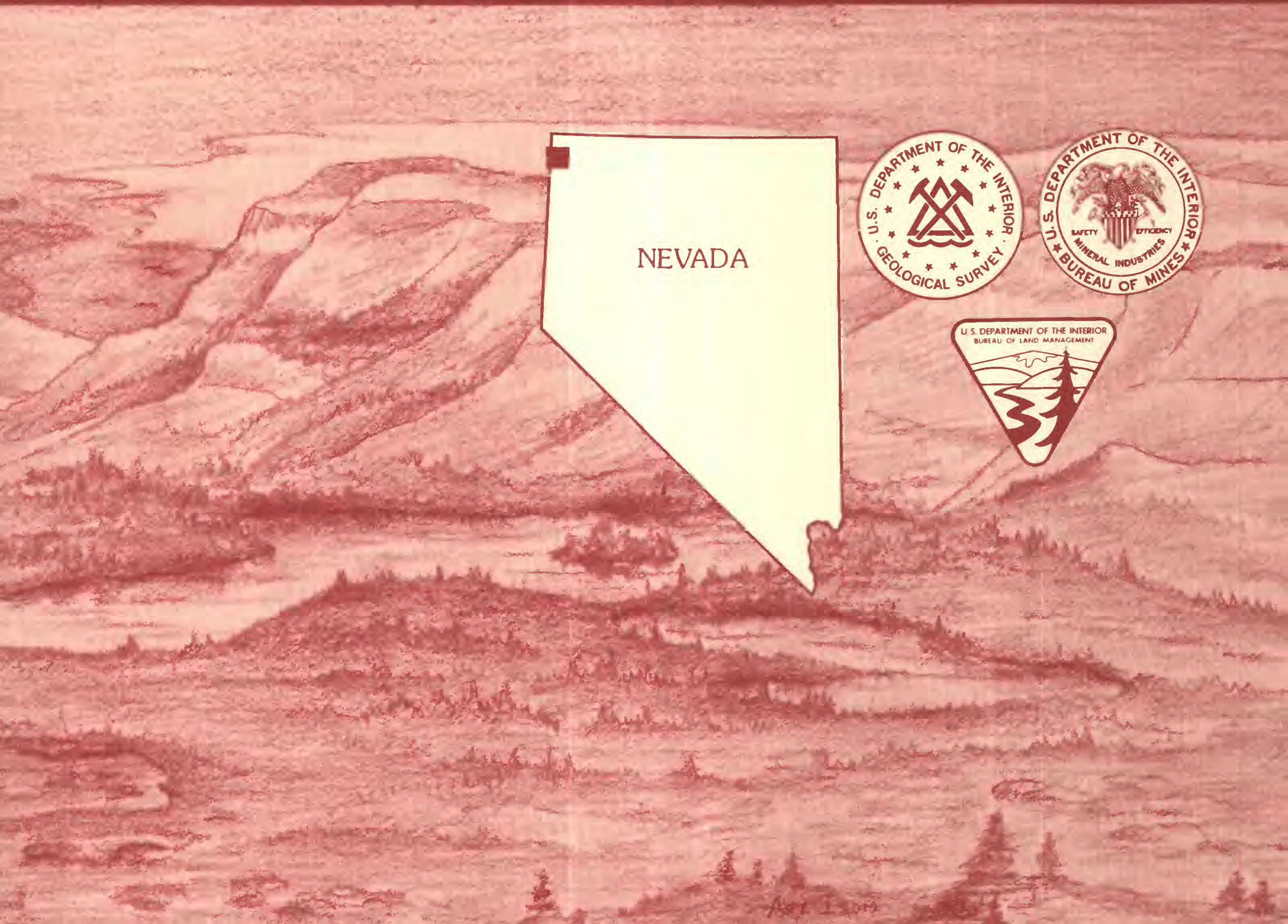

Chapter A

Mineral Resources of the Twin Peaks Wilderness Study Area, Washoe County, Nevada, and Lassen County, California

By THOMAS L. VERCOUTERE, MARTIN L. SORENSEN,
JAMES G. FRISKEN, and DONALD PLOUFF
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

DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of part of the Twin Peaks Wilderness Study Area (CA-020-619A), Washoe County, Nevada, and Lassen County, California.

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Mineral Resources of the Twin Peaks Wilderness Study Area, Washoe County, Nevada, and Lassen County, California

By Thomas L. Vercoutere, Martin L. Sorensen, James G. Frisken, *and* Donald Plouff
U.S. Geological Survey

Michael S. Miller
U.S. Bureau of Mines

SUMMARY

Abstract

At the request of the Bureau of Land Management, 50,570 acres of the Twin Peaks Wilderness Study Area (CA-020-619A) located in northwestern Nevada and northeastern California were evaluated for mineral resources (known) and mineral resource potential (undiscovered). In this report, the area studied is referred to as "the wilderness study area", or simply "the study area." The dominant rock types are basaltic and silicic volcanic rocks. There has been no mining activity, but 30 million tons of subeconomic pozzolan is inferred within the study area. The southeastern and southwestern parts of the study area have a high resource potential for pozzolan. A small area in the north-central part of the study area has moderate resource potential for gold in altered basalt breccia. Rocks exposed throughout the study area have low resource potential for copper, tungsten, and zinc. No geothermal leases exist, and the study area has low potential for geothermal resources. The study area has a low resource potential for oil and gas. The southwestern, southeastern, and eastern parts of the study area have low resource potential for sand and gravel.

Character and Setting

The Twin Peaks Wilderness Study Area is located along the northwestern edge of the Smoke Creek Desert in central Washoe County, Nev., and Lassen County, Calif., about 70 mi north of Reno, Nev. The study area is within a region characterized by north-trending block-faulted mountain ranges and extensive plateau-forming basalt flows. Twin Peaks (fig. 1), the dominant physiographic feature of the area, is the eroded remnant of a small shield volcano thought to be the source of many of the basalt flows in the region (Bonham, 1969). The eroded flanks of Twin Peaks and several deeply incised creeks provide good exposures of the Tertiary and Quaternary volcanic, intrusive, and sedimentary rocks. The oldest of these rocks are late Miocene and (or) Pliocene silicic volcanic rocks that are part of Bonham's (1969) informally named High Rock sequence. These silicic rocks are overlain by latest Miocene and Pliocene basalt and basaltic andesite flows that are intercalated with sandstone, conglomerate, and basaltic scoria. Dikes and plugs of basalt and andesite intrude the volcanic and sedimentary rocks. Young deposits, areally restricted to valleys and basin margins, include Pliocene and (or) Pleistocene basalt flows and alluvial fan deposits, Pleistocene lake deposits, and Quaternary alluvium.

Identified Resources and Mineral Resource Potential

The Twin Peaks Wilderness Study Area has no known mining history or visible evidence of mining activity. Thirty million tons of subeconomic pozzolan resources are inferred in the southwest corner of the study area.

A small area south of Mixie Flat (fig. 2) in the north-central part of the study area has moderate resource potential for gold in hydrothermally altered basalt breccia. The entire study area has low resource potential for copper, tungsten, and zinc. The southeast and southwest corners of the study area have high resource potential for pozzolan in tuffaceous lake sediments. No geothermal leases exist, and there is low potential for geothermal resources in the study area. The study area has low resource potential for oil and gas. The southwestern, southeastern, and eastern parts of the study area have low resource potential for sand and gravel in Quaternary lake and stream deposits.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management (BLM) and is a joint effort by the U.S.

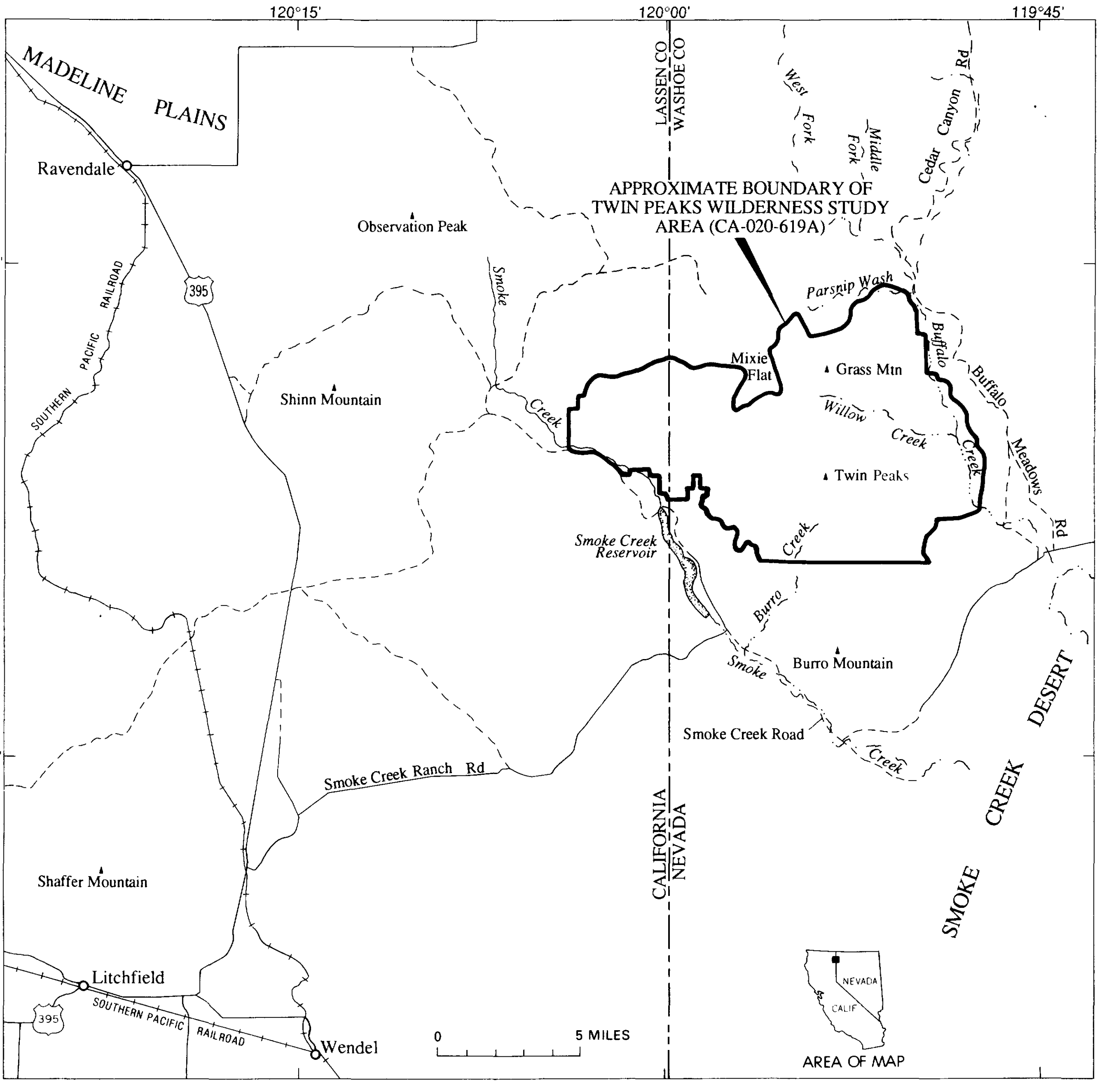

Figure 1. Index map showing location of Twin Peaks Wilderness Study Area, Washoe County, Nevada, and Lassen County, California.

Geological Survey (USGS) and the U.S. Bureau of Mines (USBM). An introduction to the wilderness review process, mineral survey methods, and agency responsibilities were 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 for mineral deposition, presence of geochemical and geophysical anomalies, and applicable ore-deposit models. Mineral-assessment methodology and terminology as they apply to these surveys were discussed by Goudarzi (1984). See the appendixes for the definition of levels of mineral resource potential and certainty of assessment and for the resource/reserve classification.

Area Description

The part of the Twin Peaks Wilderness Study Area (CA-020-619A) that the USGS and USBM studied at the request of the BLM encompasses approximately 50,570 acres of semiarid, grass- and sage-covered ridges and valleys in northwestern Nevada and northeastern California. The study area is northwest of the Smoke Creek Desert (fig. 1) in the southeastern part of the Modoc Plateau subprovince of the Basin and Range physiographic province. Gravel roads and four-wheel-drive jeep trails leading from U.S. Highway 395, to the west, and Nevada Highway 81, to the northeast, provide access to the study area (fig. 1). Elevations range from 6,592 ft at the summit of Twin Peaks to approximately 4,000 ft along the southeastern margin of the study area. Several deeply incised canyons with perennial streams dissect the area and debouch into the basin of the Smoke Creek Desert.

Previous and Present Studies

A report on the geology and mineral deposits of Washoe County (Bonham, 1969) provided preliminary information on the regional structure and stratigraphy. Information on the structural framework was supplemented by a report on the Modoc Plateau (MacDonald, 1966). A geochemical and geostatistical study prepared for the BLM by Barringer Resources, Inc. (1982) contains geochemical data for stream-sediment samples collected from this study area.

Several topical studies pertinent to the study area have been written: Russell (1885) and Benson (1978) described the geologic history of Lake Lahontan, and Phalen (1919), Overton (1947), Smith (1956), and Papke (1970) discussed mineral resources of the region.

Field investigations for this study were conducted in 1985. The USGS field checked the published geologic maps and remapped most of the study area, evaluated published geochemical data (Barringer Resources, Inc., 1982), sampled selected areas for geochemical analysis, collected and evaluated gravity data, and evaluated aeromagnetic and radiometric data. The USBM researched pertinent literature, Washoe and Lassen County mining records, and files of the USBM, Nevada Bureau of Mines, California Division of Mines and Geology, and BLM for records of mining activity. The USBM collected 15 placer and 59 rock samples from 17 mineralized sites in the study area. Three of the rock samples were examined petrographically.

Gold and silver analyses by the USBM were by combined fire assay-ICP (inductively coupled plasma analysis); other elements were analyzed by atomic absorption, colorimetry, radiometry, or X-ray fluorescence. Representative samples were analyzed for 40 elements by semiquantitative emission spectrophotometry. X-ray diffraction was used to screen selected samples for zeolite and clay minerals.

Nine samples of lake-sediment material were screened by the USBM for pozzolan suitability by analyzing oxide content for whole-rock composition (ICP) and loss on ignition. Two pozzolan samples were analyzed for pozzolan suitability by the U.S. Army Corps of Engineers, Vicksburg, Miss.

Alluvial (placer) samples were panned in the field and later concentrated in the laboratory. Detailed analytical procedures and results are given in Miller (1987). Detailed analyses are available from the USBM, Western Field Operations Center, E. 360 Third Ave., Spokane, WA 99202.

Acknowledgments

The authors gratefully acknowledge Leona Parker, John Keith, and Ernest Schofield of the Susanville BLM fire-dispatch center, for radio support, and George Wingate and Kenneth Davis of the BLM, Susanville, for providing helicopter support during field work for this study.

APPRAISAL OF IDENTIFIED RESOURCES

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

Mining and Mineral Exploration History

In 1911 and during the 1930's, at least 30 mining claims were staked outside the study area northwest of Mixie Flat, near the State boundary. Two other claims were staked about 2 mi southeast of the area in 1946 for diatomite found in the tuffaceous lake sediments. Salt and other evaporites were produced on a small scale in the late 1800's and early 1900's a few miles southeast of the study area in the Smoke Creek Desert (Russell, 1885, p. 232-233; Phalen, 1919, p. 145-146).

In 1985, there were no active claims or mining activity within or near the study area (Miller, 1987).

Mines, Mining Claims, and Mineralized Areas

No mines or mining claims were found in the study area during this study (Miller, 1987). However, mineral-bearing sites containing small or low-grade concentrations of gold, silver, copper, lead, zinc, nickel, tungsten, zeolite, and clay are present, and there are at least 30 million tons of inferred subeconomic pozzolan resources identified in the study area.

Mineral Economics

No metallic minerals were visible at the sites of metallic geochemical anomalies indicated by Barringer Resources, Inc. (1982). The amounts of lead, zinc, silver, and copper in several USBM samples, particularly those from a kaolinitic basalt breccia at Mixie Flat, confirm the geochemical anomalies of Barringer Resources, Inc. (1982) and indicate possible hydrothermal mineralization systems in or near the study area. Gold, silver, copper, lead, zinc, and nickel contents of samples taken by the USBM (Miller, 1987) were one-tenth to one-hundredth of the concentrations needed to be economic today.

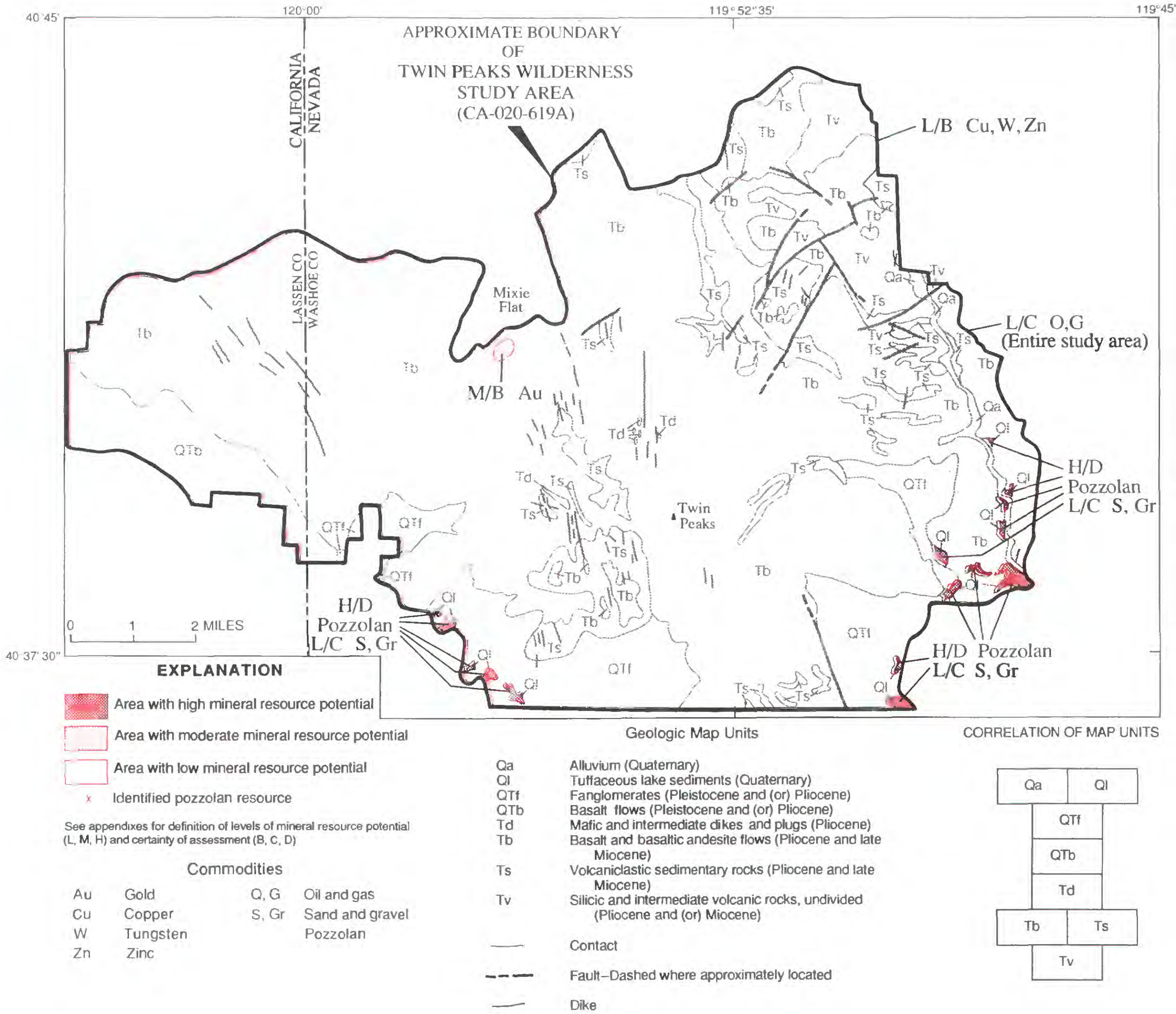

Figure 2. Generalized geology and mineral resource potential of Twin Peaks Wilderness Study Area, Washoe County, Nevada, and Lassen County, California. Geology by M.L. Sorensen and T.L. Vercoutere, 1985.

Zeolite concentrations were lower than in typical deposits by a factor of about ten, and a kaolinite deposit at the breccia pipe south of Mixie Flat is too small to be economic. No volumes or tonnages of these materials were estimated.

Although an inferred 30 million tons of subeconomic pozzolan crops out in and near the study area and could be used as a replacement for cement in some concretes, ash from coal-fired power plants currently supplies most domestic pozzolan requirements. Exploration, mining, and transportation costs (as of July, 1986) using the method of Benjamin and Gale (1984) for a 1-million-ton deposit mined at 500 tons per day with a 1:1 stripping ratio and 1 mi of truck transportation are estimated to be about $12.50 per short ton of pozzolan in the southwest corner of the study area. Probably the only domestic source of natural pozzolan being mined in 1985 was the extensive deposit of Lassenite Industries, Doyle, Calif., 50 mi southwest of the study area, at a railhead. Competition from coal ash and high transportation costs will probably keep the study area's pozzolan deposits subeconomic within the foreseeable future; the loss of ash supplies due to decreases in coal burning could improve natural pozzolan markets, as could nearby highway or dam construction.

Deposits of sand and gravel are found in many stream drainages throughout the study area, but are not classified as resources because of their small size and inaccessibility and because suitable deposits are located closer to potential markets.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Thomas L. Vercoutere, Martin L. Sorensen, James G. Frisken, *and* Donald Plouff
U.S. Geological Survey

Geology

The Twin Peaks Wilderness Study Area lies in the southeastern part of the Modoc Plateau subprovince within the Basin and Range physiographic province (MacDonald, 1966). The Modoc Plateau subprovince consists of north-trending, block-faulted ranges and intervening basins and contains numerous well-preserved constructional volcanic landforms.

The entire study area is underlain by Tertiary and Quaternary rocks (see geologic time chart in appendixes) that are either directly or indirectly volcanic in origin. They consist predominantly of basaltic and silicic flows, with mafic and intermediate dikes and plugs, and lenses of volcaniclastic sedimentary rocks that are intercalated with the basalt flows. Quaternary deposits are predominantly alluvial and lacustrine sediments. An areally restricted stack of basalt flows of Pliocene and (or) Pleistocene age (Bonham, 1969) is present in the western part of the study area.

The oldest rocks exposed in the study area are mapped as undifferentiated silicic and intermediate volcanic rocks (fig. 2). One of the two major rock types included within this unit is a bluish-white to light-gray rhyolite that includes less than 5 percent phenocrysts of feldspar, quartz, biotite, and amphibole, all less than 0.2 in. long. The other major rock type in the unit is a pinkish-gray, fine-grained, porphyritic intrusive trachyandesite that has 5 to 10 percent of 0.1- to 0.2-in. phenocrysts of plagioclase and biotite. These rocks are correlative with part of what Bonham (1969) designated as "undifferentiated High Rock Sequence and Intrusive Volcanic Rocks".

The most extensive unit in the study area consists of late Miocene and Pliocene olivine basalt and basaltic andesite flows (fig. 2) that typically are 3 to 60 ft thick. Columnar jointing is common and locally well developed. The basalt is aphyric to porphyritic, typically has phenocrysts of plagioclase (as long as 0.5 in.) and olivine, and is commonly vesicular. Basalt in this region emanated from numerous fissures and vents (Bonham, 1969). The generally consistent dip of the basalt flows away from Twin Peaks suggests that the peaks were volcanic vents.

Intercalated with the basalt flows are lenses of volcaniclastic sedimentary rocks (fig. 2) that include conglomerate, sandstone, silty sandstone, and reworked basaltic scoria. The bedding structure, internal deformation, and limited lateral extent indicate that these lenses were deposited in drainages and irregular basins of moderate to high relief that commonly contained lakes. Fragmentary fish, bird, mammal, and turtle fossils from a silty sandstone suggest that the intercalated sedimentary rocks were deposited during Early Pliocene time, probably between 3.5 and 5.0 million years ago (C.A. Repenning, written commun., 1987).

Pliocene basaltic to andesitic dikes and plugs intrude the Tertiary rocks of the study area and are clustered into three regions. A northwesterly striking dike system intrudes basalt in an area 2 to 5 mi north of the Smoke Creek Reservoir in the western part of the study area. A northerly striking dike-and-plug system intrudes basalt and sedimentary rocks 1 to 4 mi southwest, west, and northwest of Twin Peaks. A less well-constrained system has strikes that range from northwest to northeast and intrudes all three Tertiary rock units in the northeast quarter of the study area.

Other rock types exposed in the study area are Pliocene and (or) Pleistocene basalt flows along Smoke Creek in the western part of the study area and dissected fanglomerates in the southern part of the study area, Pleistocene tuffaceous lake sediments in the southeast and southwest corners of the study area, and Quaternary alluvium in active drainages.

Geochemistry

In 1982, Barringer Resources, Inc., published geochemical analyses for several thousand stream-sediment samples collected for a resource assessment in northwestern Nevada (Barringer Resources, Inc., 1982). Geochemical analysis of stream sediments is the principle method for reconnaissance geochemical exploration in areas where an integrated drainage system has developed (Meyer and others, 1979). The geochemical data obtained are a function of the composition of the rocks, sediments, and waters within the upstream catchment area. For the present study, analyses of 28 rock and 4 stream-sediment samples collected by the USGS and 111 of Barringer's analyses of stream-sediment samples collected in the study area were used. The USGS rock and stream-sediment samples were analyzed by semiquantitative emission-spectrographic methods (Grimes and Marranzino, 1968). Details of the analytical procedures and results of the USGS sampling are presented in Adrian and others (1987). All of Barringer's stream-sediment samples were analysed by inductively coupled plasma analysis (ICP), fluorimetric and colorimetric methods, and atomic-absorption spectroscopy and spectrophotometry appropriate for the elements desired. More specific information on the analytical procedures can be found in the original report (Barringer Resources, Inc., 1982). Their results for the 111 stream-sediment-sample analyses were statistically evaluated and histograms were made for each element present at concentrations above the detection limit. Concentrations were considered anomalous for each of the elements when the values were greater than two standard deviations above the mean for that element.

An area along the north boundary of the study area south of Mixie Flat (fig. 2) shows evidence of hydrothermal alteration. This area is underlain by a pipe-like structure approximately 200 ft in diameter that consists of brecciated basalt in a kaolinite matrix. Rock samples collected from this area contain anomalous concentrations of copper (130 parts per million, ppm), lead (31 ppm), zinc (180 to 200 ppm), and gold (0.075 ppm). A stream-sediment sample collected nearby also contains anomalous concentrations of copper, zinc, chromium, and tungsten; concentrations of these elements diminished in samples collected progressively downstream. The remainder of the rocks exposed within the study area have no visible evidence of mineralization or hydrothermal alteration. The Barringer study reported anomalous concentrations of barium, copper, tungsten, and zinc in stream-sediment samples collected from localities throughout the study area (Barringer Resources, Inc., 1982). These anomalous concentrations are all less than three standard deviations from the mean and represent concentrations no greater than an order of magnitude above normal crustal abundance reported by Turekian (1977). Stream-sediment samples containing anomalous concentrations of mercury (18 to 28 parts per billion, ppb) were collected from drainages in the southeastern part of the study area. While these values are considered anomalous in the study area, they do not represent a significant increase over the average of 9 or 10 ppb concentration typically found in basalts (Turekian, 1977), and the variation in mercury content within the study area may only represent variation in magmatic concentration. Copper content in 27 of the 28 basaltic dikes analyzed is less than 70 ppm; one dike has an anomalous concentration of copper (300 ppm).

Geophysics

The results of a regional aeromagnetic survey for the Nevada part of the study area (U.S. Geological Survey, 1972) indicate that the average magnetic intensity level is about 200 to 300 nanoteslas (nT) higher than the regional intensity levels in surrounding areas. A broad magnetic high with two crests covers most of the southern half of the study area. The amplitude of the magnetic high is about 400 nT. The broad magnetic high generally reflects the high regional elevation of the study area because the flight level here is closer to the normally magnetized volcanic rocks than when over the surrounding areas. The presumed volcanic vent at Twin Peaks is located along the north-northwest-trending axis of the eastern crest of the broad magnetic high. The saddle in the magnetic high is located along a north-northwest-trending line between Burro Creek at the south edge of the study area and Mixie Flat outside the north edge of the study area. Closed magnetic lows occur at both ends of the line segment. The location of the magnetic saddle does not strongly correlate with topography, as would be expected where the surface rocks have significant magnetization. Therefore, the magnetic saddle probably reflects rocks of lower magnetization beneath the volcanic rocks exposed at the surface. Cenozoic volcanic rocks may form a relatively thin veneer over a structural or erosional high of less-magnetic pre-Cenozoic basement rocks along the saddle.

In 1985, 10 gravity stations in the study area and 17 stations within 3 mi of the study area boundary were established by the USGS and were combined with 4 previously established stations in California (Snyder and others, 1982) and 2 in Nevada (Allen H. Cogbill, written commun., 1985). A preliminary Bouguer gravity-anomaly map (Plouff, unpub. data) displays a conspicuous gravity high that coincides with the previously discussed magnetic saddle, both extending about 5 mi south of the study area. The gravity high and alignment of magnetic lows may reveal the location of a pre-Cenozoic basement high that incorporates rocks that are denser and less magnetic than surrounding Cenozoic rocks. The east flank of the high forms the west edge of a gravity low centered more than 4 mi southeast of the study area, over the north end of the Smoke Creek Desert. A northwestward decrease of about 2.5 milligals per mile, starting near the southeast edge of Mixie Flat, forms another conspicuous gravity anomaly. Gravity contours within this gradient are approximately linear and may indicate underlying deep-seated fault control.

Radiometric data were compiled by Geodata International, Inc. (1978), in Nevada and by Western Geophysical Company of America (1981) in California for the National Uranium Resource Evaluation (NURE) program of the U.S. Department of Energy. The coverage of the study area in Nevada consists of three east-west flightlines and one north-south flightline totaling about 31 mi. No flightlines crossed the part of the study area in California. Recordings were made of gamma-ray flux from radioactive isotopes of uranium, thorium, and potassium. Count rates about one standard deviation above mean background level for all three isotopes were recorded near and to the east of Grass Mountain, along a flightline located 2 mi south of the northmost edge of the study area. The cause of this anomaly is likely to be higher radioactivity emanating from the silicic volcanic rocks. Ground-based scintillometer readings showed the gamma-ray flux at outcrops of the silicic volcanic rocks to be greater than that at outcrops of the surrounding mafic rocks. Along the west half of the flightline that is located 0.5 mi north of the south edge of the study area, count rates for all three isotopes were one standard deviation below mean background level. The low values may be an effect of rock alteration.

Mineral Resource Assessment

Geologic, geochemical, and geophysical investigations suggest limited mineral resource potential in the wilderness study area (fig. 2). Hydrothermally altered basalt breccia collected by the USBM from south of Mixie Flat contains detectable gold (0.075 ppm). This area has moderate resource potential for gold, certainty level B.

The entire study area has a low resource potential for copper, tungsten, and zinc, certainty level B. The rating is based on anomalous concentrations of these elements in stream-sediment and rock samples.

Quaternary tuffaceous lake sediments exposed in the southeast and southwest corners of the study area have a high resource potential for pozzolan, certainty level D, in addition to the 30 million tons of inferred subeconomic pozzolan resources already identified.

Although hot springs occur in adjacent ranges, no evidence of geothermal activity was seen in or near the study area. No geothermal leases exist in the Twin Peaks Wilderness Study Area. The area has low potential, certainty level B, for geothermal resources.

The potential for oil and gas resources in the study area is low, certainty level C. This evaluation is based on the absence of organic-rich rocks that might be a source of hydrocarbons and the lack of suitable reservoir rocks.

The potential for sand and gravel resources in the southwestern, southeastern, and eastern study area is low, certainty level C, in the Quaternary alluvium.

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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

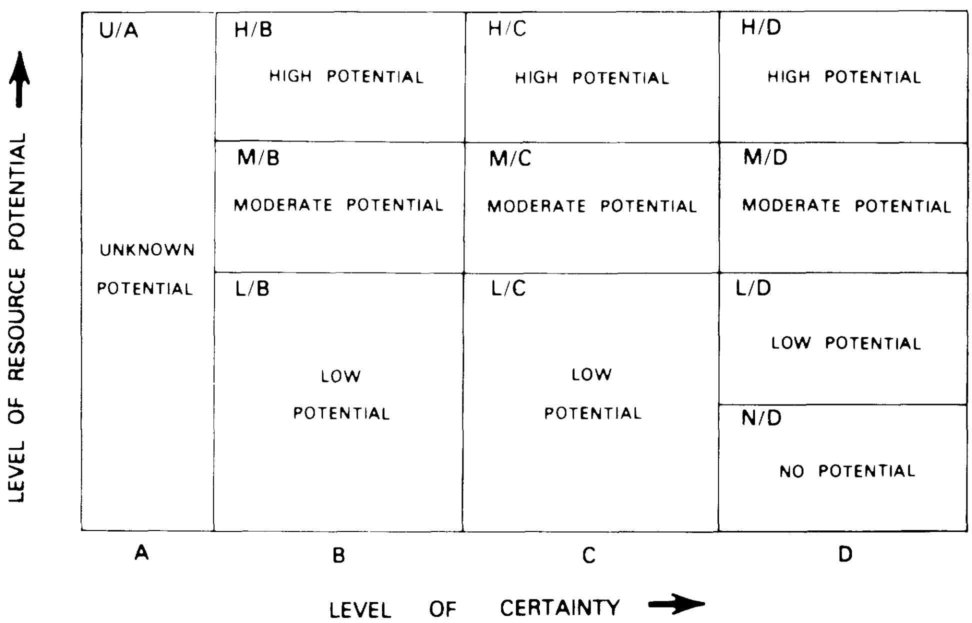
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate reasonable likelihood of resource accumulation, and (or) where an application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

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

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

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

Levels of Certainty



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

Abstracted with minor modifications from:

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

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

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

RESOURCE/RESERVE CLASSIFICATION

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

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

GEOLOGIC TIME CHART

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

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

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

[2]Informal time term without specific rank.

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U.S. DEPARTMENT OF THE INTERIOR

March 3, 1849