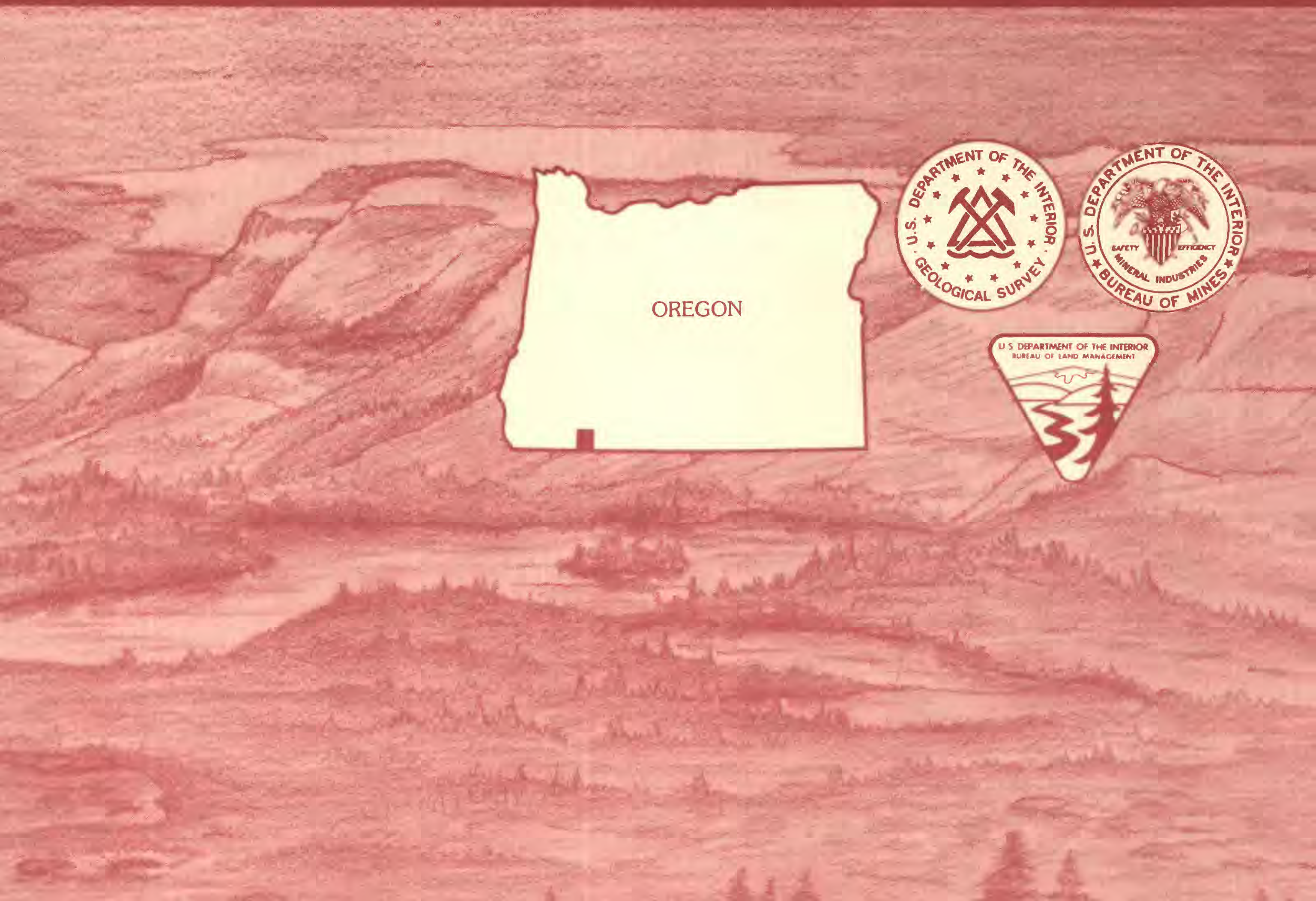
Mineral Resources of the Soda Mountain Wilderness Study Area, Jackson County, Oregon

U.S. GEOLOGICAL SURVEY BULLETIN 1744-C



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Chapter C

Mineral Resources of the Soda Mountain Wilderness Study Area, Jackson County, Oregon

By WILLIAM J. PICKTHORN, RICHARD J. GOLDFARB, DONALD PLOUFF, STEVEN J. SUTLEY, and MARK D. WILCOX
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THOMAS J. PETERS and SPENCEE L. WILLETT
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U.S. GEOLOGICAL SURVEY BULLETIN 1744

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
CENTRAL AND FAR WESTERN OREGON

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

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

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Area

The Federal Land policy and Management Act (Public Land 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys of 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 mineral surveys of the Soda Mountain Wilderness Study Area (OR-011-017), Jackson County, Oregon.

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Mineral Resources of the Soda Mountain Wilderness Study Area, Jackson County, Oregon

By William J. Pickthorn, Richard J. Goldfarb, Donald Plouff, Steven J. Sutley, *and* Mark D. Wilcox
U.S. Geological Survey

Thomas J. Peters and Spencee L. Willett
U.S. Bureau of Mines

SUMMARY

Abstract

At the request of the Bureau of Land Management, 5,640 acres that comprise the Soda Mountain Wilderness Study Area (OR-011-017), in south-central Oregon, were evaluated for mineral resources (known) and mineral resource potential (unknown). In this report the area studied is referred to as "the wilderness study area." The dominant rock types in the study area are basaltic and andesitic flows and breccia and minor outcrops of silicic tuff. Although there are no identified resources and there has been no significant prospecting activity, an outcrop of altered silicic tuff in the northern part of the study area has been prospected for gold. Much of the northern part of the study area has moderate potential for gold and silver. The study area has a low potential for geothermal resources. The study area has low resource potential for oil and gas and building stone; a small area in the south has low potential for gold in placer deposits.

Character and Setting

The Soda Mountain Wilderness Study Area is located along the west flank of the Cascade Range in Jackson County, Oregon, about 17 mi southeast of Ashland, Oregon (fig. 1). Approximately 75 percent of the densely vegetated study area comprises steep ridges and canyons forming the south face of Soda Mountain. Total relief of the study area is about 3,000 ft with a maximum elevation of 5,760 ft. The study area is underlain by gently northeast-dipping Oligocene (see appendixes for geologic time chart) volcanic and volcaniclastic rocks, principally basalt and andesite.

Manuscript approved for publication, September 4, 1990.

Identified Resources and Mineral Resource Potential

The Soda Mountain Wilderness Study Area has no identified mineral resources or significant prospecting activity. However, the small Soda Mountain prospect was located in an area of hydrothermally altered silicic tuff and andesite breccia on a ridge northeast of Camp Creek; it consists of a 7-ft-deep shaft and a nearby shallow pit. Gold values of the altered rocks at the prospect are as high as 0.06 oz per ton. Geochemical data from rock and soil samples suggest more mineralization south of the prospect area; that area is assigned a moderate potential for gold. Much of the northern part of the study area is also assigned moderate potential for gold and silver on the basis of geochemical evidence. No geothermal leases exist in the study area and there is a low potential for geothermal resources. There is also low potential for oil and gas resources. The possibility of placer gold and building stone resources was also investigated, but no occurrences were observed; their potential is also assigned as low.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management (BLM) and is a cooperative effort of 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 is 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 a system that is a modification of that described by McKelvey (1972) and the 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 the application of ore-deposit models. Methodology and terminology as they apply to these mineral assessment 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 Soda Mountain Wilderness Study Area is situated along the west flank of the Cascade Range, approximately 17 mi southeast of Ashland, Oregon, immediately north of the California border. Best access is by an improved BLM dirt road that leads south from Oregon Highway 66 at Green Springs to a fire lookout tower and microwave relay facility on the peak of Soda Mountain on the north edge of the study area. Access is also possible by dirt roads and jeep trails east from Interstate Highway 5 near Siskyou, and north from Irongate Reservoir in northern California. Elevations in the study area range from 2,920 ft at Salt Creek to 5,760 ft on the flank of Soda Mountain. Most lower

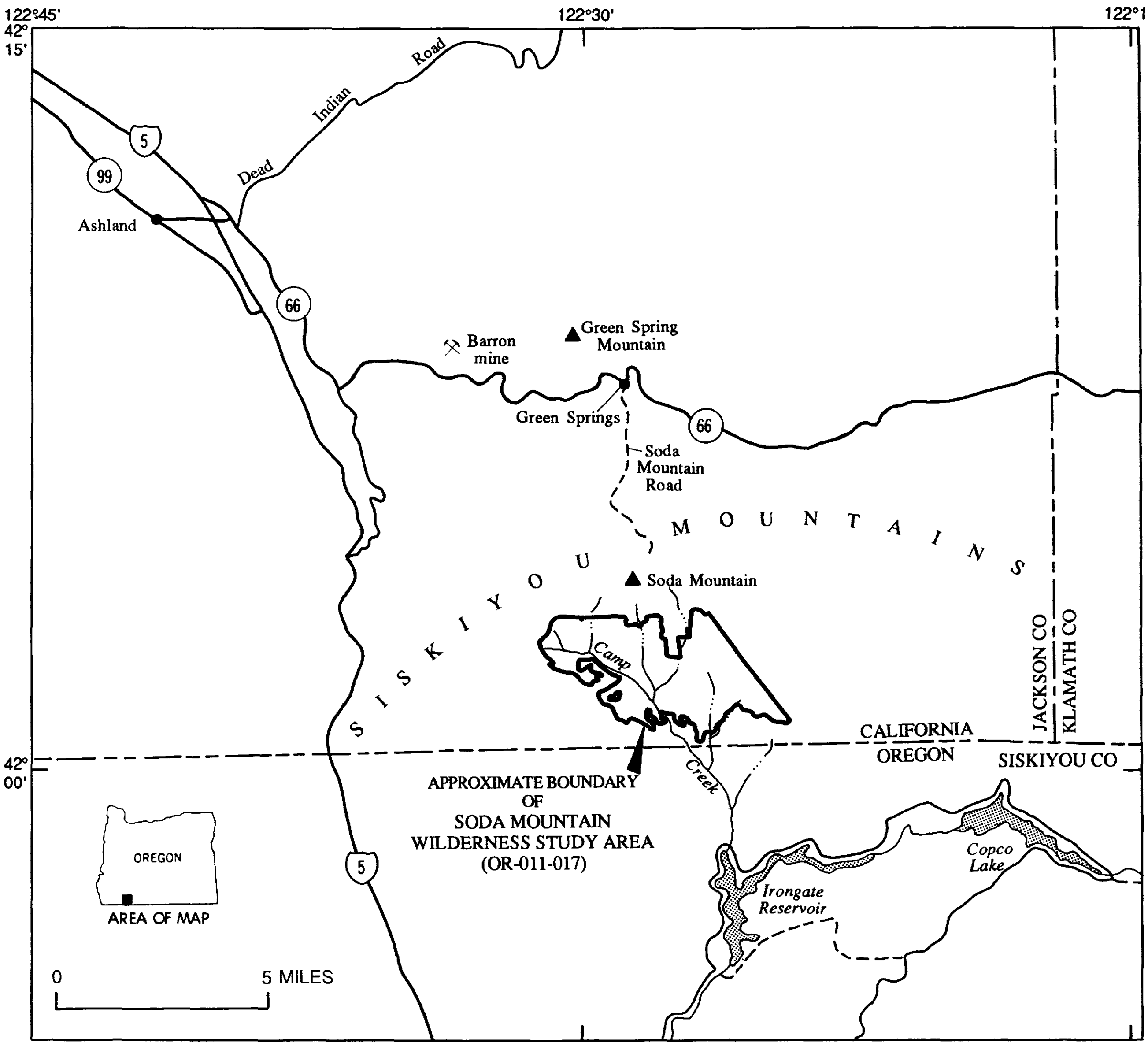


Figure 1. Index map showing location of Soda Mountain Wilderness Study Area, Jackson County, Oregon

elevation slopes and stream valleys are covered by dense brush, and the higher ridges are vegetated by pine and fir. Open grasslands are present on the gentle slopes in the eastern part of study area.

Previous and Present Studies

Geologic mapping, geochemical sampling, geophysical studies, and mineral-assessment studies that include the Soda Mountain Wilderness Study Area were done on a regional scale for the Medford 1° by 2° quadrangle. These studies are listed and summarized in Smith and others (1986). Geologic mapping by Wells (1956) covered a small part of the west edge of the study area.

Detailed field investigations by the USGS were conducted in the Soda Mountain Wilderness Study Area during the summer and fall of 1988 and spring of 1989. This work included geologic mapping, geochemical sampling, and examination of outcrops for evidence of alteration and mineralization. The geochemical survey utilized rock and stream-sediment (including a fine-fraction and heavy-mineral-concentrate) samples that were analyzed for 37 elements by semiquantitative emission spectrography. All rocks were analyzed for gold and mercury by atomic absorption, and for arsenic, bismuth, cadmium, antimony, and zinc by inductively coupled plasma spectroscopy (ICP). Geophysical data, which consisted of gravity information collected during the Medford quadrangle study, and aeromagnetic data collected by Oregon State University and covering the Cascade Range were analyzed and interpreted.

The USBM examined prospects and mineralized zones within and adjacent to the study area to evaluate identified mineral resources. Prefield preparation included a library search of pertinent geological and mining literature, BLM master title plats, and current mining claim recordation data. Information was also obtained from the Oregon Department of Geology and Mineral Industries at Grants Pass, and the USBM Mineral Industries Location System (MILS). A field search was conducted for mines, prospects, and mineralized areas in and near the study area. Mineralized sites were examined and mapped. Ninety-eight samples were collected; these included 41 rock, 52 soil, and five alluvial samples. Rock samples were analyzed for nine major-element oxides, LOI (loss of ignition), and 34 trace elements. Soil samples were analyzed for 34 trace elements, and alluvial samples were analyzed for free gold and other heavy minerals (Peters and Willett, 1989).

Acknowledgments

The authors are grateful to Joseph G. Dauenhauer, owner of the Barron mine, for permission to visit the mine, and to John Archer for showing us the property. Edward D. Fields, Boise Cascade Corporation, Spokane, Wash., and Len Ramp, Oregon Department of Geology and Mineral Industries, Grants Pass, provided valuable geological information. Gerry Capps, James Renthal, and Fred Tomlins, BLM, Medford, and Thomas Maier, U.S. Forest Service, Prospect, Oreg., and Steve Bulkin, U.S. Forest Service, Medford, Oreg., provided information and logistical support. James G. Smith of the USGS provided insight to the geology and resource appraisal.

APPRAISAL OF IDENTIFIED RESOURCES

By Thomas J. Peters *and* Spencee L. Willett
U.S. Bureau of Mines

Mining and Mineral Exploration History

Although mining in southwest Oregon dates back to the 1850's, there has been relatively little activity in the volcanic and volcaniclastic terrane of the southern Oregon Cascade Range. Minor exploration activity has occurred at the Soda Mountain prospect, as evidenced by a 7-ft-deep shaft and shallow pit; the identity of the prospector(s), however, is not known. At least one company engaged in gold exploration has visited the prospect prior to this study.

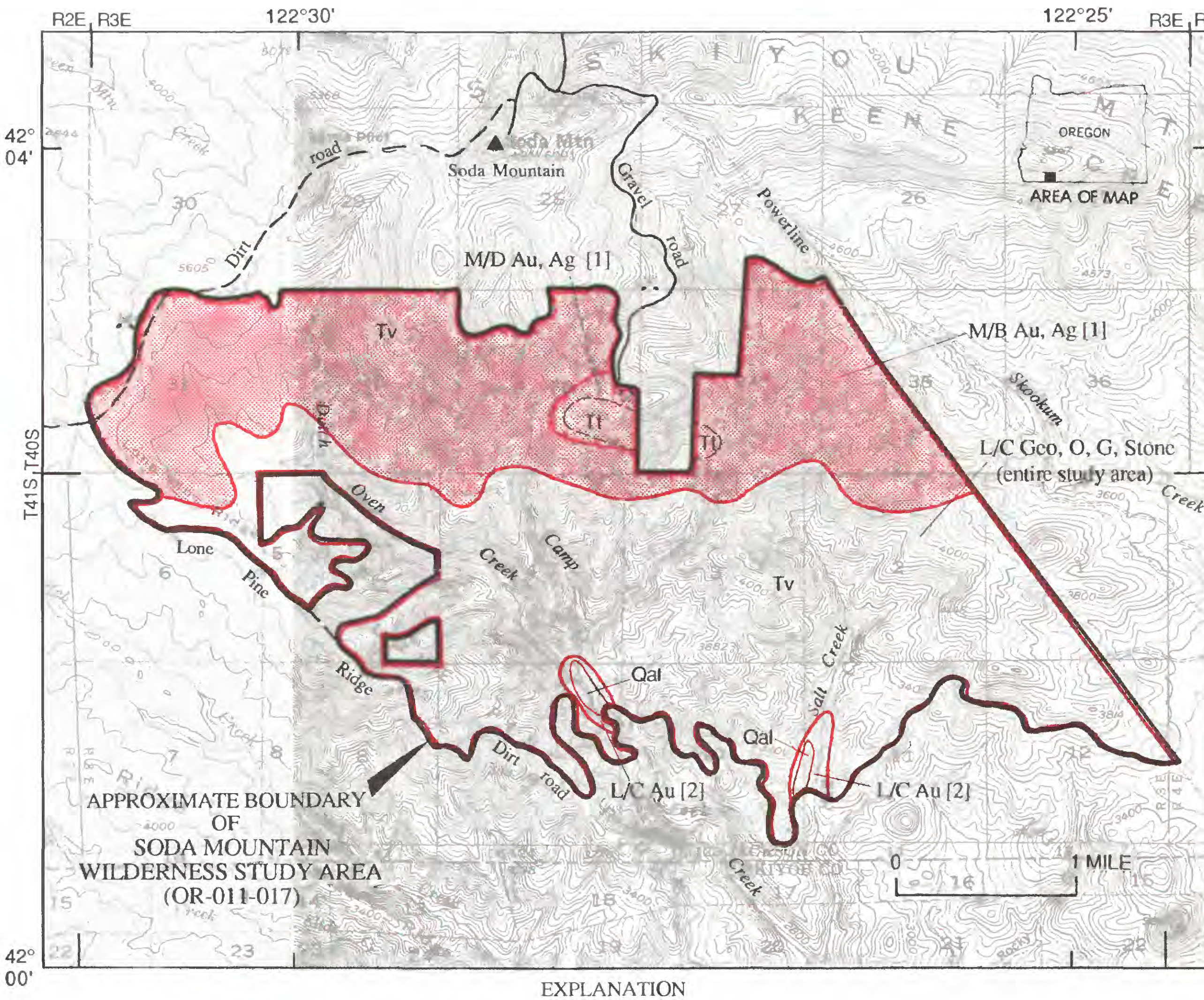
BLM mining claim records show a lode claim was located in the N1/2 of section 6, township 41 S., range 3 E., on November 20, 1983, by Myrle E. and Betty Dodson of the Medford area; the authors were unable to contact the Dodsons. The claim must have been in or near the west corner of the wilderness study area, probably along Lone Pine Ridge (fig. 2). A ground search of the area disclosed no evidence of mineralization or exploration and mining activity.

Mark Hermiston, BLM geologist, Medford, collected 28 stream-sediment and five rock samples from the wilderness study area and vicinity during a reconnaissance geochemical survey (Rimal, 1985, p. 50-53).

Soda Mountain Prospect/Mineralized Area

Access to the Soda Mountain prospect is by the Soda Mountain Road, south from Green Springs Mountain on Oregon Highway 66 (fig. 2). The prospect area straddles the study area boundary (fig. 2). The only known workings consist of a 7-ft-deep, 3-ft-diameter shaft and a shallow pit. The prospect lies on the north edge of area underlain primarily by pervasively kaolinized and silicified rhyolite tuff.

This siliceous tuff and andesite in the prospect area (Peters and Willett, 1989, pl. 1) are cut by prominent steeply dipping joint sets trending between N. 60° W. and N. 75° E., and clustering at N. 70° W. and N. 80° E. Limonite, goethite, and hematite are present on the joints and frac-



EXPLANATION

Area having moderate mineral resource potential (M)

Area having low mineral resource potential (L)

Levels of certainty of assessment
- B Data only suggest level of potential
- C Data give good indication of level of potential
- D Data clearly define level of potential

Commodities
- Ag Silver
- Au Gold
- Geo Geothermal
- O, G Oil and gas
- Stone Building stone

Deposit types
- [1] Epithermal vein
- [2] Placer

Description of map units
- Qal Alluvium (Quaternary)—Mostly unconsolidated stream sand and gravel
- Tv Volcanic rocks (Tertiary)—Basalt, basaltic andesite, and andesite flows and breccia; age is Oligocene
- Tt Tuff (Tertiary)—Silicic ashflow tuff; may be aquagene, in part

Contact—Dashed where approximately located

Soda Mountain prospect

Borrow pit

Figure 2. Mineral resource potential and generalized geology of Soda Mountain Wilderness Study Area, Jackson County, Oregon. Base from U.S. Geological Survey 1:62,000-scale Ashland (1954) and Hyatt Reservoir (1955) quadrangles, Oreg.-Calif. Contour interval 40 and 80 ft.

tures. Epidote alteration and weak arsenopyrite mineralization were also observed. Flow banding is not apparent in most places, but in the prospect area it dips 30° E. where observed.

Mineral Economics and Resources

Gold concentrations in rock and soil samples from the Soda Mountain prospect (Peters and Willett, 1989) delineate a 10-acre gold-bearing mineralized zone. Three rock samples from the southern part of the prospect area contained 280, 210, and 2,100 parts per billion (ppb) (0.008, 0.006, and 0.06 oz per ton) gold, respectively, worth $3.30, $2.40, and $24.80 per ton at a $400 per oz gold price.

Possible occurrences of placer gold and building stone resources were also investigated (Peters and Willett, 1989, p. 11), but no resources were identified. Five alluvial samples from streambeds draining the study area contained placer gold with an in situ value of 0, 2, 2, 5, and 20 cents per yd^3 at a $400 per oz gold price; no extensive alluvial bars were observed. None of the stone observed had special physical properties, such as splitting into flat slabs useful for facing stone, nor special chemical properties, such as an extraordinarily high alumina content suitable as an alternative source of aluminum ore in the distant future. The stone appears to have value only as road metal, a low-value, high-volume end use economically suitable for local application only; ample supplies of stone are present locally outside the study area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By William J. Pickthorn, Richard J. Goldfarb, Donald Plouff, Steven J. Sutley, *and* Mark D. Wilcox
U.S. Geological Survey

Geology

The Soda Mountain Wilderness Study Area lies along the west flank of the Cascade Range and the geology consists of volcanic and volcaniclastic rocks of the Cascade Volcanic Arc. These rocks were erupted during the Oligocene and early Miocene Epochs (Smith and others, 1986). This sequence is collectively called the volcanic rocks of the western Cascade Range. In southern Oregon the volcanic rocks of the western Cascade Range are structurally simple, forming a homoclinal sequence that dips gently north-northeast. Because of shifting eruptive centers and the interfingering and overlapping of volcanic and sedimentary units, a simple stratigraphic sequence does not exist. Rapid facies changes are common within a single unit.

The study area lies entirely within a single regional reconnaissance volcanic unit mapped by Smith and others (1982) as Oligocene basalt, basaltic andesite, and andesite. Individual depositional units have varying appearance due to textural changes, rather than compositional changes, and thus were not mapped separately. Much of the study area is covered by dense brush and extensive soils are developed on the slopes. Smith and others (1982) indicate no major faults in their mapping, and none were noted in this study. Small landslides are present on the steeper slopes and on the south face of Soda Mountain.

Several outcrops of a recently mapped silicic tuff (Peters and Willett, 1989) are present in the northern part of the study area, along a tributary to Camp Creek. The tuff unit appears to pinch and swell and the thickness could not be accurately determined. The unit appears to be dominantly bedded, suggesting an aquagene origin in part. Fragments of the tuff present along Camp and Dutch Oven Creeks suggest that the tuff may extend to the west but no outcrops were observed in the thick brush.

Geochemical Studies

The geochemical survey of the Soda Mountain Wilderness Study Area consisted of the collection and analysis of eight stream-sediment and heavy-mineral-concentrate samples and 31 rock samples from inside, and immediately adjacent to, the study area. Stream-sediment samples were air-dried and sieved to minus-80-mesh fractions. All concentrate samples were panned from 1.5 to 2 lb of minus-10-mesh sediment using a gold pan. In the laboratory, the concentrates were air-dried, the lighter material was removed using bromoform, and the magnetic heavy-mineral fractions were removed using a magnetic separator. Sediment and rock samples were analyzed for 35 elements and nonmagnetic concentrate samples were analyzed for 37 elements using optical emission spectrography according to the method outlined by Grimes and Marranzino (1968). In addition, all rocks and sediments were analyzed by atomic-absorption spectrometry for gold, all rocks were analyzed by atomic-absorption spectrometry for mercury, and all sediments and selected altered rocks were analyzed by ICP for arsenic, bismuth, cadmium, antimony, and zinc. Complete analytical data and a detailed discussion of the sampling and analytical methods are given in Sutley and others (1990).

With the exception of samples collected from the Soda Mountain prospect, most of the lithogeochemical data for basalt, andesite, vein quartz, and jasperoid samples show background levels for all elements studied. Gold concentrations were below the 50 ppb lower determination limit and most mercury concentrations were less than 100 ppb. One quartz vein, however, contained 120 ppb mercury with no other anomalous element values. The only significant geochemical anomalies were for hydrothermally altered siliceous volcanic breccia and tuff samples collected at the Soda Mountain prospect. These altered rocks contain as much as 1.5 parts per million (ppm) silver, 127 ppm arsenic, greater than 2,000 ppm boron, 10 ppm bismuth, 2.9 ppm mercury, 100 ppm lead, and 28 ppm antimony. Some samples are slightly enriched in copper, molybdenum, and tin compared to samples from the rest of the study area. None of the anomalous rocks, however, contained detectable gold at the 50-ppb lower determination limit. However, Peters and Willett (1989) report as much as 2.10 ppm gold, as well as 19 ppm, silver, 11,200 ppm arsenic, 2.3 ppm mercury, 1,724 ppm lead, and 76 ppm antimony, for altered tuff from the prospect. This discrepancy in reported chemical analyses is most likely due to "nugget effect."

Stream-sediment and heavy-mineral-concentrate data suggest other areas of weakly altered volcanic rocks elsewhere within the study area. The three stream sediments collected along the east edge of the study area are weakly anomalous in silver, arsenic, and (or) zinc. Sediment and concentrate samples collected near the junction of Camp and Dutch Oven Creeks contain above-background concentrations of silver, arsenic, boron, and (or) lead, a suite of elements similar to those elements present in anomalous concentrations in the altered rock samples. Microscopic examination of the most anomalous heavy-mineral-concentrate sample, collected on Dutch Oven Creek about 100 yd above its junction with Camp Creek, revealed the presence of grains of pyrite, arsenopyrite, and galena.

Geophysical Studies

Geophysical evaluation of the mineral resources of the study area was based on interpretations of aeromagnetic and gravity surveys.

As part of the USGS Geothermal Program, Oregon State University was funded to collect aeromagnetic data in the Cascade Range. The area surrounding the study area was flown at an elevation at 9,000 ft above sea level along east-west flightlines spaced approximately 1 mi apart (Couch and others, 1981; Couch, 1982) (fig. 3). Most of the study area lies along the south and southwest edges of an east-west-elongated aeromagnetic high (fig. 3). The shape and location of the aeromagnetic high generally reflects moderate magnetization of underlying andesite to basalt flows (Smith and others, 1982), as confirmed by the presence of a local magnetic crest of the magnetic high over Soda Mountain. Magnetic gradients extending over horizontal distances of nearly 2 mi near the study area suggest that the thickness of the causative magnetic body or bodies substantially exceeds that of volcanic rocks that crop out near the study area. The aeromagnetic high centered north of the study area is situated near the south edge of a prominent set of magnetic highs that extend north-northwestward for about 60 mi. Blakely (1986) interpreted the set of magnetic highs as possibly being caused by a fault-bounded underlying ultramafic sheet or a thick sequence of Tertiary volcanic rocks. The magnetic gradients in the study area apparently reflect a steeply dipping or fault-bounded interface between deep-seated plutonic or volcanic rocks and surrounding, less magnetic basement rocks. The magnetic gradient is interrupted along the south edge of the study area by a magnetic low. The magnetic low probably is caused by rocks of low magnetization in and beneath a 1-mi-diameter outcrop of mafic intrusive rocks of Tertiary age centered at the south edge of the study area (Smith and others, 1982).

The USGS established eight gravity stations in and within 3 mi from the border of the study area during a regional mineral appraisal of public lands in the Medford 1° by 2° quadrangle (R.J. Blakely, written commun., 1989). These data were supplemented with gravity data obtained from Oregon State University as part of Blakely's compilation. Locations, elevations, and terrain corrections for these data were revised to reflect topography on 7 1/2-minute topographic maps published since the original gravity data were collected. North-northwest-trending contours in the region generally reflect thickening of the crust away from the Pacific coast and a decrease of the local gravity anomaly toward a regional gravity trough along the Cascade Range (Blakely and others, 1985). The most prominent feature of the gravity map of the study area is a gravity high centered near the southwest edge of the study area and its enclosing gravity contours (fig. 4). The shape of the contours and the position and orientation of the gravity high are uncertain because there are only a few stations in the area. The location of the gravity high and, consequently its source, is also uncertain because its effect is superimposed on a strong

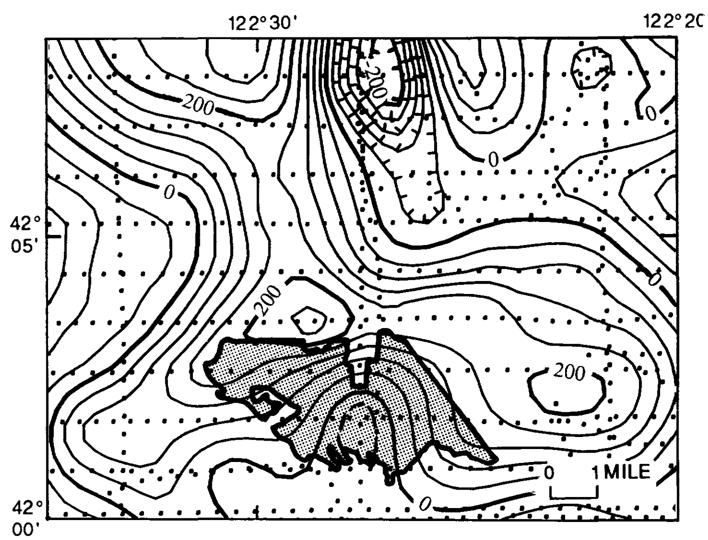


Figure 3. Aeromagnetic map of Soda Mountain Wilderness Study Area, Oregon (shaded). Values of magnetic intensity of Earth's magnetic field in nanoTeslas (nT) (1 nT=1 gamma) at arbitrary datum; International Geomagnetic Reference Field has been removed. Contour interval 40 nT; dot, magnetic station; contours hachured in direction of lower magnetic intensities. Dashed line, center of magnetic low discussed in text.

regional gravity gradient. We speculate that the source of the gravity high that interrupts the regional gradient also is associated with the underlying source of the mafic intrusive rocks that crop out nearby.

Mineral and Energy Resource Potential

Geologic, geochemical, and geophysical investigations suggest potential for epithermal precious metal mineralization in the Soda Mountain Wilderness Study Area. Singer and others (1983) indicate much of the area on the Medford 1° by 2° quadrangle that is underlain by Tertiary volcanic rocks is favorable for epithermal vein mineralization. One such area, based on rock samples with anomalous boron, mercury, and tellurium concentrations, is present approximately 1 mi north of the study area boundary. Also, the Barron mine, a past producer of gold and silver, is located within the Tertiary volcanic rocks about 10 mi northwest of the study area.

Hydrothermally altered silicic tuff and andesite breccia samples collected by the USBM and USGS from the area of the Soda Mountain prospect contain significant concentrations of gold and silver. This area has moderate resource potential for gold and silver, certainty level D. Stream-sediment and heavy-mineral-concentrate samples containing anomalous concentrations of many elements characteristic of epithermal mineralization suggest that other parts of the study area, lacking adequate outcrop exposure, may contain similar zones of alteration and possibly underwent gold-silver mineralization. These areas, along the north edge of the study area and within the Dutch Oven Creek watershed, have a moderate resource potential for gold and silver, certainty level B.

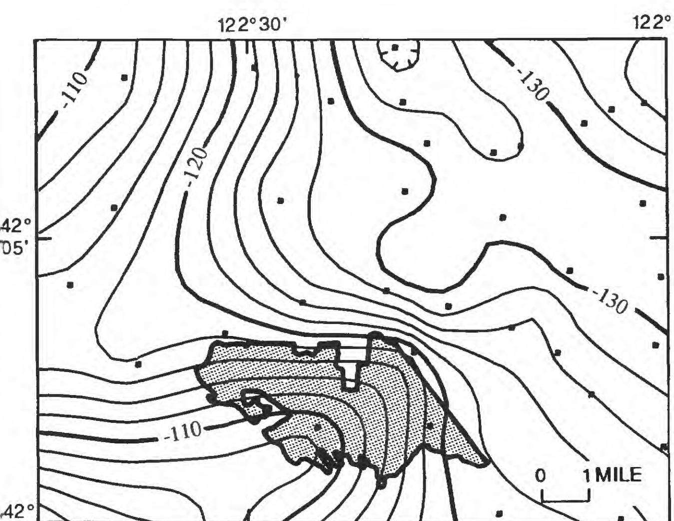


Figure 4. Bouguer gravity anomaly map of Soda Mountain Wilderness Study Area, Oregon (shaded). Gravity values in milliGals; contour interval 2 milliGals; dot, station location; contours hachured in direction of lower gravity values. Reduction density 2.67 g/cm³.

The potential for geothermal resources in the study area is low, certainty level C. Areas of active geothermal energy and exploration are associated with silicic volcanism less than 2 Ma (million years) (Smith and Shaw, 1975) or areas of high heat flow, neither of which are present here.

The potential for oil and gas resources in the study area is low, certainty level C. This evaluation is based on the absence of suitable source or reservoir rocks.

The potential for building stone is also low, certainty level C.

A small area in the southern part of the study area has low potential for gold in placer deposits, certainty level C.

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LEVELS OF RESOURCE POTENTIAL

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

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

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

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

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

LEVELS OF CERTAINTY

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

B Available information only suggests the level of mineral resource potential.

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

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

LEVEL OF RESOURCE POTENTIAL →

A	B	C	D
U/A	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 →

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RESOURCE/RESERVE CLASSIFICATION

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

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

GEOLOGIC TIME CHART

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

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

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

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