Mineral Resources of the Spaulding Wilderness Study Area, Lake and Harney Counties, Oregon

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Chapter E

Mineral Resources of the Spaulding Wilderness Study Area, Lake and Harney Counties, Oregon

By MICHAEL G. SAWLAN, HARLEY D. KING, and DONALD PLOUFF
U.S. Geological Survey

MICHAEL S. MILLER
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1738

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
SOUTH-CENTRAL OREGON

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

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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 the Spaulding Wilderness Study Area (OR-001-139), Lake and Harney Counties, Oregon.

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Mineral Resources of the Spaulding Wilderness Study Area, Lake and Harney Counties, Oregon

By Michael G. Sawlan, Harley D. King, *and* Donald Plouff
U.S. Geological Survey

Michael S. Miller
U.S. Bureau of Mines

SUMMARY

Abstract

The Spaulding Wilderness Study Area (OR-001-139) is located along the east side of Guano Valley in southern Oregon. At the request of the U.S. Bureau of Land Management, 34,800 acres of the Spaulding Wilderness Study Area was evaluated for mineral resources (known) and mineral resource potential (undiscovered). In this report, the area studied is referred to as the "Spaulding Wilderness Study Area" or the "study area."

There are no identified resources in the study area. Two groups of mining claims and a small prospect pit are located in the study area. No workings are found near the claims and no mining claims are current. There are no mineral leases and no oil and gas leases or lease applications. The northwestern and southeastern parts of the study area have low potential for epithermal (low-temperature) gold and silver (precious-metal) resources; trace amounts of gold were detected in alluvium in the northwestern part of the study area, and anomalous concentrations of elements commonly associated with precious-metal deposits were found in the southeastern part of the study area. The study area contains occurrences of pozzolanic tuff, perlite, and building stone. The sand and gravel occurrences in the study area are small and of poor quality. The study area has low potential for oil and gas. There is no potential for geothermal, uranium, or thorium resources.

Character and Setting

The Spaulding Wilderness Study Area (OR-001-139) is located along the east side of Guano Valley in Lake and Harney Counties, Oregon, about 8 mi north of the Oregon-Nevada State line (fig. 1). The study area encompasses 34,800 acres, mostly mesas and rolling hills east of Guano Rim. The northwestern part of the study area includes low-lying areas in the north end of Guano Valley.

Access to the study area is via State Highway 140, about 10 mi south of the study area; gravel roads and jeep trails connect with State Highway 140 and encircle the study area. The nearest towns are Adel, Oregon, about 25 mi west of the study area, and Denio, Nevada, about 45 mi southeast of the study area. National antelope refuges and ranges are located south, west, and northwest of the study area. The study area lies in the northern Basin and Range province and encompasses part of the range between Guano Valley and Hawks Valley. Relief in the area is moderate; elevations range from about 5,250 ft in Guano Valley to about 6,250 ft on the mesas in the central part of the study area.

The study area is underlain by flat-lying to gently dipping middle and late Miocene volcanic rocks (see "Appendixes" for geologic time chart), which include andesite lava and tuff breccia, ash-flow tuff, tuffaceous sedimentary rocks, and basalt. The western part of the study area is underlain mostly by andesite, which forms the steep scarp along Guano Rim. The central part of the study area is underlain by mesa-forming basalt and tuffaceous sedimentary rock. The eastern part is underlain by ash-flow tuff, which forms a terrain of gently rolling hills and low-lying bluffs.

Identified Resources

There are no identified resources in the Spaulding Wilderness Study Area. County mining records show that two groups of mining claims, apparently for the same site, were located in the study area. However, none of these claims is current and there are no mineral leases. No ongoing mineral exploration is known in or adjacent to the

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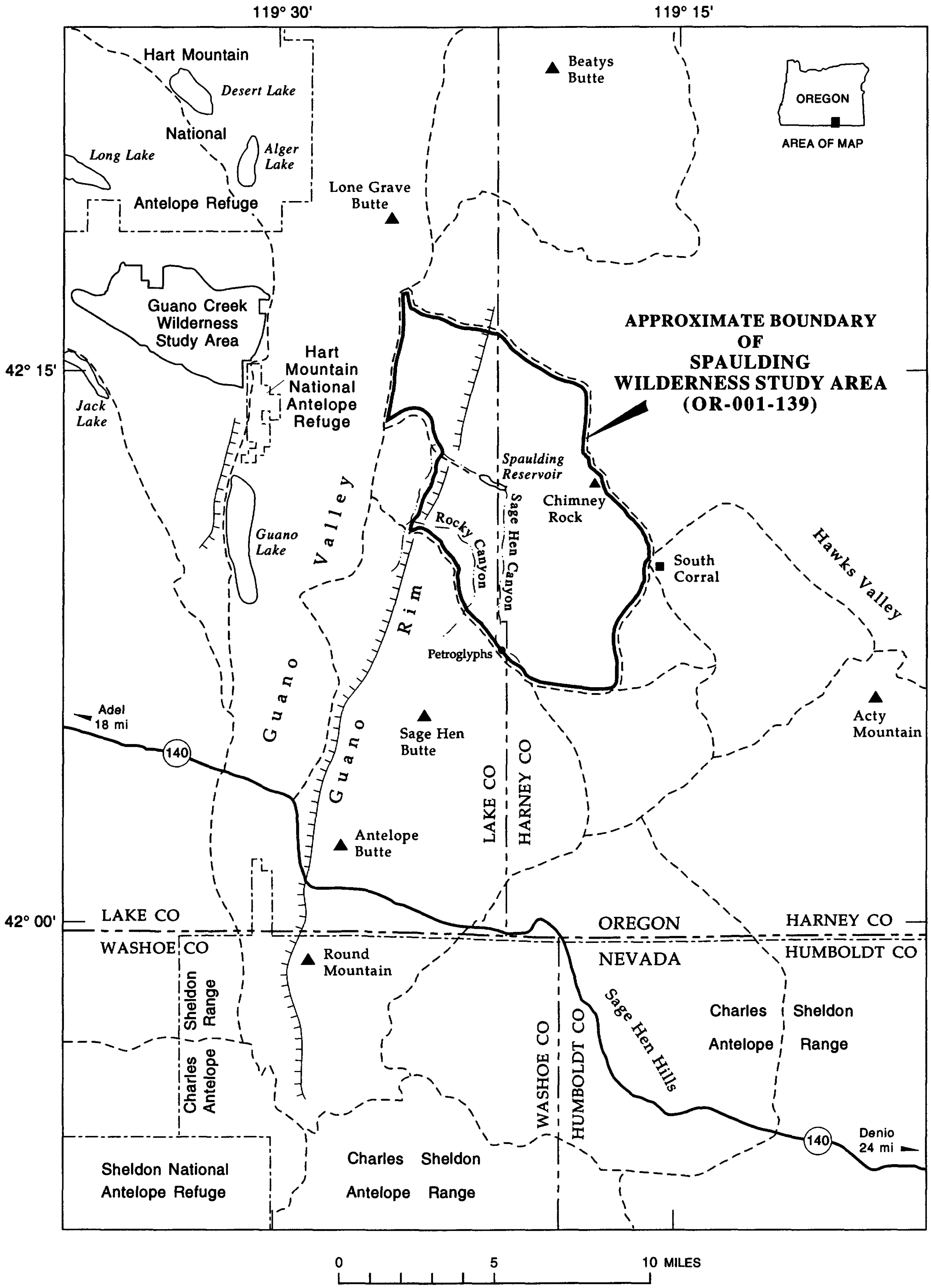

Figure 1. Index map showing location of Spaulding Wilderness Study Area, Lake and Harney Counties, Oregon. Unlabeled dashed lines represent gravel roads and (or) jeep trails.

study area. The northern part of the study area contains occurrences of pozzolanic tuff. These are not regarded as resources because markets for pozzolanic tuff are limited and similar materials are located close to existing markets. Occurrences of stone and small amounts of low-grade perlite are present in and near the study area but also do not constitute resources.

Mineral Resource Potential

The northwestern and southeastern parts of the Spaulding Wilderness Study Area have low potential for gold and silver resources (fig. 2). Alteration and (or) geochemical anomalies for elements commonly associated with epithermal precious-metal deposits are found in small, scattered areas. Trace amounts of free gold are present in alluvial gravel in the northwestern part of the study area. Analysis of a surficial clast of altered rock from Guano Valley reveals a trace amount of gold (4 parts per billion (ppb)). Geochemical anomalies of silver and other elements (lead, barium, bismuth, and zinc) typically associated with epithermal precious-metal deposits are present in heavy-mineral concentrates of stream sediment samples from the southeastern part of the study area, about 2 mi southwest of South Corral. Geochemical anomalies of antimony, arsenic, barium, tungsten, and molybdenum are also present in rock samples of black, glassy veins in ash-flow tuff near Chimney Rock in the eastern part of the study area. The presence of manganiferous iron-oxide veins in upper Sage Hen canyon in the southern part of the study area indicates past hydrothermal activity. Samples from there contain anomalous concentrations of one or more of the following elements: arsenic, mercury, barium, cadmium, and bismuth.

The entire study area has low potential for oil and gas even though there are no indications in the surface geology to indicate the presence of either hydrocarbon source rocks or structural traps. There are no oil and gas or geothermal leases or applications. No geothermal energy or uranium and thorium resources were identified.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management and is the result of a cooperative effort by the U.S. Geological Survey and the U.S. Bureau of Mines. An introduction to the wilderness review process, mineral survey methods, and agency responsibilities was provided by Beikman and others (1983). The U.S. Bureau of Mines evaluates identified resources at individual mines and known mineralized areas by collecting data on current and past mining activities and through field examination of mines, prospects, claims, and mineralized areas. Identified resources are classified according to the system modified from that described by McKelvey (1972) and the U.S. Bureau of Mines and U.S. Geological Survey (1980). Studies by the U.S. Geological Survey are designed to provide a reasonable scientific basis for assessing the potential for undiscovered mineral resources by determining geologic units and structures, possible environments of mineral deposition, presence of geochemical and geophysical anomalies, and applicable ore-deposit models. Goudarzi (1984) discussed mineral assessment methodology and terminology as they apply to these surveys. See “Appendixes” for the definition of levels of mineral resource potential and certainty of assessment and for the resource/reserve classification.

Location, Character, and Setting

The Spaulding Wilderness Study Area is located in the High Lava Plains physiographic province in the northern Basin and Range geologic province. The study area encompasses part of the low mountain range between Guano Valley to the west and Hawks Valley to the east (fig. 1). Much of the study area consists of basalt mesas; the terrain in the southeastern part of the study area consists of low rolling hills. A steep, north-northeast-trending escarpment, 500 to 800 ft high, bounds the east side of Guano Valley and coincides with the boundary of the west-central part of the study area. The extreme northwestern part of the study area lies in Guano Valley. Relief in the study area is moderate; elevations range from about 5,250 ft in Guano Valley to about 6,250 ft on basalt mesas in the central part of the study area. Beatys Butte, Lone Grave Butte, and Mahogany Butte (north of area shown in fig. 1) are remnants of ancient volcanoes that dominate the landscape to the north.

Several antelope Ranges and Refuges lie peripheral to the study area (fig. 1). The Hart Mountain National Antelope Refuge is about 5 mi west and northwest of the study area. The Sheldon National Antelope Refuge and the Charles Sheldon Antelope Range include large areas south of the study area mostly in Nevada. Indian petroglyphs are found in the southernmost part of the study area where potholes in basalt along Sage Hen Canyon form small catch basins for water. The climate is arid and sparse rainfall results in only intermittent stream flow and inundation of shallow ephemeral lakes.

Previous Investigations

The Adel 1° by 2° quadrangle, which includes the study area, was previously mapped in reconnaissance at a scale of 1:250,000 by Walker and Repenning (1965); this map was later compiled in a 1:500,000-scale geologic map

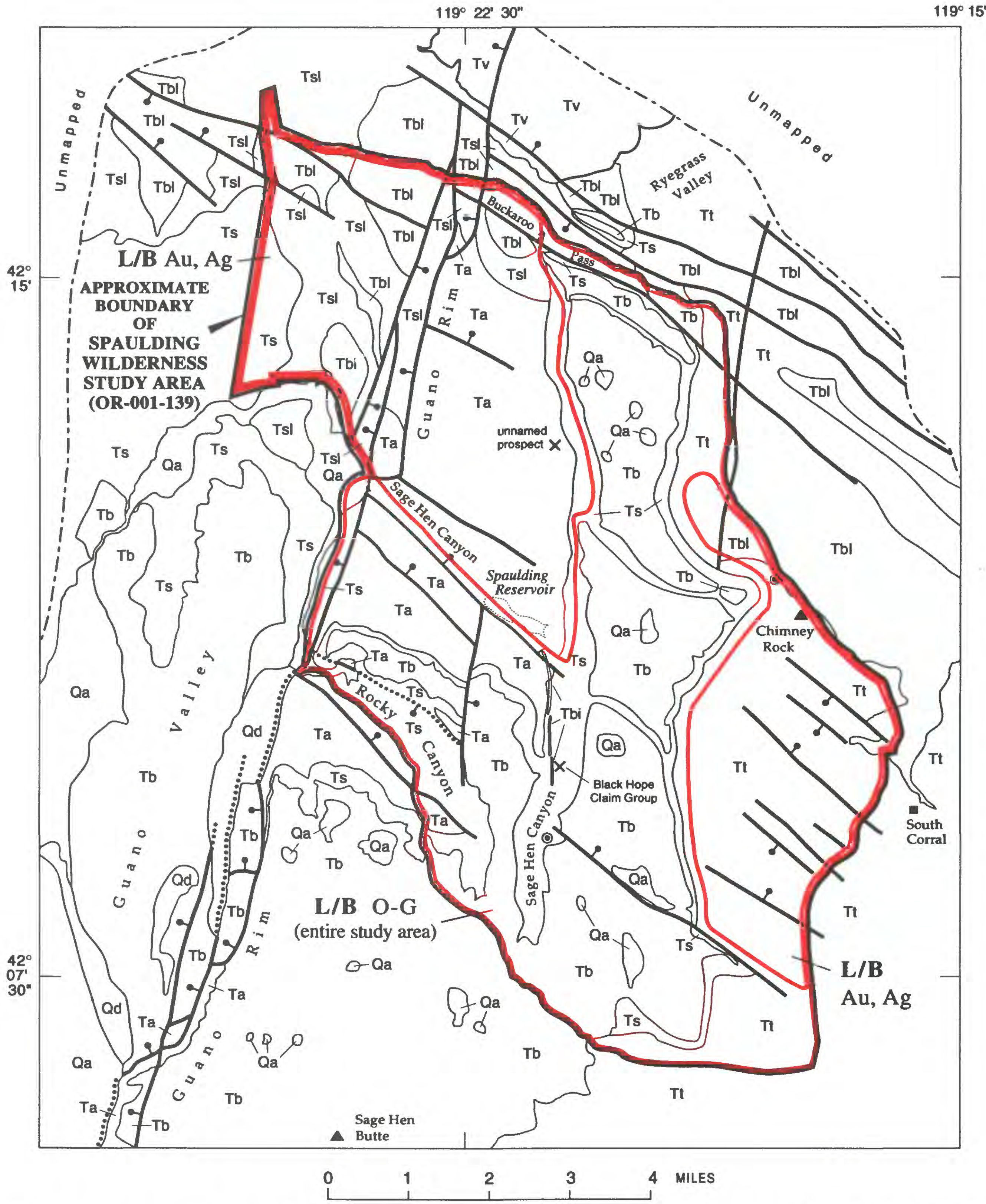

Figure 2. Mineral resource potential and generalized geology of Spaulding Wilderness Study Area, Lake and Harney Counties, Oregon.

EXPLANATION

☐	Area with low mineral resource potential (L)
	Levels of certainty of assessment
B	Data only suggest level of potential
	Commodities
Au	Gold
Ag	Silver
O-G	Oil and Gas
	Map units
Qa	Alluvium (Quaternary)
Qd	Aeolian sand (Quaternary)
Tv	Undifferentiated volcanic rocks (late Miocene?)
Tbi	Basalt dikes (middle Miocene)
Tb	Upper basalt (middle Miocene to early Pliocene)
Ts	Upper tuffaceous sedimentary rocks (middle Miocene to early Pliocene)
Tsl	Lower tuffaceous sedimentary rocks (middle Miocene)
Tbl	Lower basalt (middle Miocene)
Tt	Ash-flow tuff—Includes Idaho Canyon Tuff of Greene (1984) and tuff of Ryegrass Valley (middle Miocene)
Ta	Andesite (middle Miocene)
	Contact
	Fault—Ball and bar on downthrown block, dotted where concealed
×	Claim or prospect
◉	Mineral occurrence—(see sections "Prospects, Claims, and Mineral Occurrences" and "Alteration and Mineralization")

Figure 2. Continued.

of eastern Oregon by Walker (1977). The geology of an area about 6 mi south of the study area to about 25 mi into Nevada was mapped by Greene (1984) for a mineral resource assessment of the Charles Sheldon Wilderness Study Area. Diggles and others (1988) reported on the mineral resources of the Guano Creek Wilderness Study Area about 5 mi west of the northwestern part of the study area (fig. 1).

The study area is included in several regional geophysical and geochemical surveys aimed at assessing potential for uranium resources (Erikson and Currey, 1977; Geodata International, 1980, Union Carbide Corp., 1982). A summary of the geology, energy resources, and mineral resources of the study area was reported by Matthews and Blackburn (1983).

Present Investigations

In 1987, the U.S. Geological Survey (USGS) conducted field investigations which consisted of geologic mapping at a scale of 1:24,000, field checking of existing maps, interpreting aerial photographs, geochemical sampling, and examining outcrops for evidence of mineralization. In all, 87 rock samples, 49 stream sediment samples, and 49 heavy-mineral-concentrate samples panned from stream sediment were analyzed at USGS laboratories.

Work by the U.S. Bureau of Mines (USBM) included examining literature on the geology, mines, and prospects in and near the study area. Federal, State, and county records were examined to ascertain the location of mines or mineral claims in the study area. Field studies, conducted in 1986 and 1987, included examining, mapping, and geochemical sampling of prospects, claims, and mineralized areas in and adjacent to the study area. Eighteen alluvial and 30 rock samples were collected. The alluvial samples were concentrated and examined for economic minerals. Rock samples were analyzed by private laboratories for a suite of elements related to formation of mineral deposits. Samples from nonmetallic sources with likely industrial uses were analyzed with respect to their pertinent physical properties. Samples were checked in the field and in the laboratory for radioactivity. Sampling procedures and results of the USBM investigations of the study area are presented by Miller (1988).

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John R. Benham, William N. Hale, Richard A. Winters, Thomas J. Peters, and J. Douglas Causey (USBM, Western Field Operations Center, Spokane, Wash.), and Dennis Simontachi (U.S. Bureau of Land Management, Lakeview, Oreg.) assisted M.S. Miller in the field. Mark Wick assisted M.G. Sawlan in geologic investigations. J.L. Jones and T.A. Delaney (USGS, Denver, Colo.) assisted

H.D. King in collecting stream sediment and panned-concentrate samples. D.R. Keitzman assisted Donald Plouff in collecting geophysical data. Douglass Troutman and Dennis Simontachi (U.S. Bureau of Land Management, Lakeview, Oreg.) provided maps and logistical information to M.G. Sawlan.

APPRAISAL OF IDENTIFIED RESOURCES

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

Prospects, Claims, and Mineral Occurrences

There is no record of mineral production from within the Spaulding Wilderness Study Area. Two groups of mining claims have been located in the study area, but none of these claims is active. One group of claims was first staked about a mile east of Spaulding Reservoir in 1919. In 1943, this claim group was relocated to the south in Sage Hen Canyon and named the Black Hope claim group (fig. 2). There are no identified resources in the Spaulding Wilderness Study Area.

Metallic Commodities

An area in the Chimney Rock area (fig. 2) was reported by Erikson and Currey (1977) to contain uranium and by the U.S. Department of the Interior (1939, 1941) to contain mercury. Uranium and mercury concentrations from weakly altered rock in this area are at levels typical of tuffs that underlie the surrounding region. Two samples of black glassy veins in welded tuff from about 0.5 mi northwest of Chimney Rock are weakly anomalous in barium (1,500–5,000 parts per million (ppm)), molybdenum (20–39 ppm), and arsenic (5–6 ppm). These veins may be similar to manganiferous veins in the upper part of Sage Hen canyon, which contain 500 to more than 5,000 ppm barium, as much as 20 ppm molybdenum, and as much as 62 ppm arsenic, based on USGS investigations (see "Geochemical Studies"). Manganese was not analyzed, however, in samples of the veins from near Chimney Rock.

A small unnamed prospect pit lies about 2 mi north of Spaulding Reservoir (fig. 1). There, rocks adjacent to a basaltic dike exhibit limonite and hematite staining and clay alteration. Silver (16 parts per million (ppm)) is present in one sample of scoriaceous basalt, and platinum (30 ppb) is present in another.

Platinum (less than 15 ppb to as much as 30 ppb) and palladium (less than or equal to 2 ppb) are present in 7 of 8 samples from three unaltered basaltic dikes. Few analyses for platinum and palladium in basalt are available for comparison but these platinum and palladium values and platinum:palladium ratios (about 7 to 15) are high compared to those of Siberian flood basalt, for example, which contains platinum and palladium in subequal amounts, at concentrations typically in the range of 2 to 10 ppb. Platinum and palladium values in basalt from the study area are about 200 to 1000 times lower than the minimum grade of ore, approximately 5 to 20 ppm, from deposits of platinum-group elements that are currently being mined (M. Zientek, oral comm., 1992). There are no resources of platinum-group minerals in the study area.

Alluvium in the northwestern part of the study area contains traces of free gold. Microscopic flakes of gold are present in nine 0.3 ft^3 alluvial samples. Alluvium at these sites is estimated to contain approximately 0.00003 to 0.0009 troy ounces of gold per yd^3, worth about $0.12 to 0.36 per yd^3 at a gold price of $400 per troy ounce (oz). The alluvium has no current economic value as a gold placer.

Analyses of five rock samples from the western part of the study area show silver in concentrations ranging from 5 to 16 ppm. These samples are of pumiceous tuff, a basalt dike, scoriaceous basalt, and friable silty sandstone. Although minor amounts of limonite, hematite and clay are present in these rocks, none contain anomalous concentrations of arsenic, antimony, mercury, or other metals characteristically associated with epithermal precious-metal mineralization.

Nonmetallic Commodities

Nonmetallic commodities include uneconomic occurrences of perlite and pozzolan. The Black Hope claims encompass an area in Sage Hen Canyon along a 2-mi-long, north-trending basalt dike. The dike cuts tuff that, in a 2- to 3-ft-wide envelope along the margins of the dike, was partially fused to rhyolite glass during intrusion of the dike; the rhyolite glass has since hydrated to form perlite. No workings are found near the claims. Perlitic glass is also present in fiamme in densely welded ash-flow tuff outside the southeastern boundary of the study area. Perlite occurrences in and near the study area are of poor quality and unsuitable for commercial development and use. Tuffaceous rocks in the northwestern corner of the study area meet the chemical definition of pozzolan established by the American Society for Testing and Materials (1985). The pozzolan might be suitable as an additive to cement, but detailed testing to evaluate compatibility with specific cement mixes would be required. Similar pozzolanic rocks are widespread throughout the Basin and Range province and, therefore, it is likely that materials closer to markets would be mined before pozzolan from the study area.

Energy Resources

No energy resources were identified in the study area. There are no oil and gas or geothermal leases or lease applications for land in the study area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Michael G. Sawlan, Harley D. King, *and* Donald Plouff
U.S. Geological Survey

Geology

The Spaulding Wilderness Study Area lies in the northern Basin and Range province, an area characterized by north-trending ranges and intervening basins bounded by normal faults. The study area includes part of a north-trending range bounded on the west by faults along Guano Rim and on the east by Hawks Valley (fig. 1). The study area is underlain by flat-lying to gently dipping middle Miocene to early Pliocene volcanic and volcaniclastic sedimentary rocks including andesite, two sequences of basalt and tuffaceous sedimentary rocks, and ash-flow tuff (fig. 2). These rocks range in age from about 16 to 5 Ma (mega-annum, or million years). This age range is defined by K-Ar (potassium-argon) ages cited by Greene (1984), and new K-Ar ages acquired during this study (J.E. Conrad, USGS, written commun., 1989) and that of the Guano Creek Wilderness Study Area (M.F. Diggles, USGS, written commun., 1990).

Surficial deposits in the study area include thin accumulations of alluvial gravel, sand, and silt along drainages and in ephemeral lakes. Aeolian sand dunes are present southwest of the study area in the eastern part of Guano Valley. Small alluvial fans along the scarp east of Guano Valley have a conical shape which indicates that relative subsidence of Guano Valley, along faults that form the scarp of Guano Rim, has occurred in Quaternary time and perhaps is ongoing.

Description of Lithologic Units

Andesite (Ta)

The oldest rocks exposed in the study area are andesite and basalt(?) lava and andesite tuff breccia that underlie the western part of the study area, mostly within 2 to 3 mi of Guano Rim (fig. 2). These rocks generally dip gently, less than 10°, to the southeast. This unit is mostly porphyritic andesite with abundant plagioclase phenocrysts, but includes sparsely porphyritic basaltic andesite or basalt with phenocrysts of olivine±plagioclase±clinopyroxene. The andesite tuff breccia is a rock type commonly attributed to lahars, or mudflows, deposited on the distal flanks of andesitic composite volcanoes.

The andesite in the study area and the surrounding region is about 17 to 14 Ma old. Two K-Ar ages on andesite from the mouth of Rocky Canyon (fig. 1) adjacent to Guano Valley are 16.2±0.5 and 14.2±1.5 Ma (J.E. Conrad, written commun., 1989). Basaltic andesite from the hills along the west side of Guano Valley has been dated at 17.0±0.5 Ma (M.F. Diggles, written commun., 1990). Andesite from Bald Mountain at the south end of Guano Valley (about 2 mi south of the southwest corner of fig. 1) has been dated at 15.3±0.9 Ma (E.H. McKee, written commun., 1990, previously cited by Greene, 1984).

Ash-Flow Tuff (Tt)

Two petrologically distinct ash-flow tuffs are found in and adjacent to the study area: poorly welded tuff in Ryegrass Valley northeast of the study area, and the Idaho Canyon Tuff, which underlies most of the southeastern part of the study area. Minor amounts of unwelded lapilli tuff and tuffaceous sedimentary rocks are also included in this unit. In the study area, the Idaho Canyon Tuff mostly consists of devitrified, vapor-phase altered, moderately welded tuff containing about 6 to 10 percent phenocrysts of alkali feldspar, quartz, and lesser amounts of fayalite. Locally, this tuff shows dense welding, vitrophyric layers, and poorly welded layers containing abundant pumice lapilli. It probably contains more than one cooling unit. The Idaho Canyon Tuff extends at least 20 mi south into Nevada and its age is about 15.5 to 15 Ma (Greene, 1984). It overlies the tuff of Craine Creek, dated at 15.7±0.5 Ma (Noble and others, 1970), and it underlies the Summit Lake Tuff, dated at 15.1±0.5 Ma (Noble and others, 1970), which are both present in Nevada. Ash-flow tuff exposed northeast of the study area, here informally named the tuff of Ryegrass Valley, consists of poorly welded white tuff containing biotite phenocrysts. This tuff is overlain by the lower basalt unit. Stratigraphic relations between the Idaho Canyon Tuff and the andesite lavas were not observed.

Lower Basalt (Tbl)

Gently tilted basalt flows are present in and adjacent to the northern part of the study area (fig. 2). In Guano Valley, this basalt contains abundant, large plagioclase phenocrysts–these lavas may be correlative with the Steens Mountain basalt, which is widespread in southeastern Oregon. These lavas are cut by northwest-trending faults and dip about 5 to 15° southwest or northeast. Correlation of the lower basalt from the east and west sides of the study area is uncertain. Along the east margin of the study area, the basalt contains sparse olivine(?) phenocrysts and dips about 5 to 10° southeast. The lower basalt in this area underlies the Idaho Canyon Tuff and overlies the biotite-bearing ash-flow tuff that crops out in Ryegrass Valley. The age of the lower basalt is not certain but is at least 15 Ma, the age of the Idaho Canyon Tuff (Greene, 1984). This lower basalt unit locally includes tuffaceous sedimentary rocks that are intercalated with the basaltic lavas; thicker sections of these sedimentary rocks were mapped separately as the lower tuffaceous sedimentary rocks unit (unit Tsl).

Lower Tuffaceous Sedimentary Rocks (Tsl)

This unit includes poorly exposed tuffaceous sedimentary rocks intercalated with the lower basalt. These rocks are distinguished from the upper tuffaceous sedimentary rocks by their stratigraphic association with the lower basalt (see "Upper Tuffaceous Sedimentary Rocks" section).

Upper Tuffaceous Sedimentary Rocks (Ts)

This unit includes poorly bedded, weakly lithified, friable, and tuffaceous nonmarine sandstone, siltstone, and minor amounts of conglomerate. Some beds locally contain abundant rhyolite pumice lapilli. These pumice-rich deposits may represent airfall or reworked deposits of airfall or unwelded tuff. The poorly lithified rocks of this unit generally are preserved only where overlain by basalt. This unit typically is poorly exposed and forms gentle grassy or talus-covered slopes beneath basalt mesas. Mammalian fossils are found locally within this unit; during this study, bone fragments were found in the southeastern corner of the study area. Both the upper and lower tuffaceous sedimentary rocks are poorly exposed, have a similar appearance in the field, and are distinguished by stratigraphic position in relation to the lower and upper basalts. The upper tuffaceous unit may include rocks of the lower tuffaceous unit where intercalated basalt is absent and exposures are poor.

Upper Basalt (Tb)

The upper basalt unit consists of mesa-forming basalt in the east-central and southwestern parts of the study area, and basalt in Guano Valley. Individual flows are typically 15 to 40 ft thick, are aphyric or contain sparse phenocrysts of olivine±plagioclase, and have a characteristic diktytaxitic groundmass texture. At most localities, 1 to 3 lava flows have a composite thickness of 60 ft. or less. These basalts differ markedly in chemical composition from the andesite of unit Ta; that is, they have very low amounts of potassium and generally high amounts of nickel, chromium, and cobalt compared to most volcanic rocks. These basalts belong to the suite of low-potassium tholeiitic basalt, which is widespread throughout southern Oregon (Hart and others, 1984).

This upper basalt unit includes two groups of basalt that are petrographically similar but differ in age. An older group of lavas forms the north-trending band of mesas in the eastern part of the study area. A younger group of lavas includes the basalt mesa between Sage Hen and Rocky canyons, the broad basalt mesa southwest of the study area, and basalt in Guano Valley (fig. 2).

These basalts are late middle Miocene to early Pliocene, but dating of these rocks has been imprecise due to analytical difficulties caused by their low K_2O (potassium oxide) contents. Basalt belonging to the older group has not been dated directly but it is probably between 13 and 9 Ma. The older group may be correlative with mesa-forming basalt at Gooch Table, about 16 mi south of the study area, which has a K-Ar age of 9.9±1.2 Ma (E.H. McKee, USGS, written commun., 1990; cited by Greene, 1984). The age of a basalt dike in Sage Hen canyon, which perhaps fed some lavas of the older group, is about 13 Ma (see "Basalt Dikes"). A K-Ar age of 5.1±1.5 Ma on basalt of the younger group, from the mesa south of Spaulding Reservoir, was obtained during this study (J.E. Conrad, written commun., 1989).

Basalts of the older group forms gently south-dipping mesas that may differ in elevation as much as 220 ft. Although only one or two basalt flows are present at most localities, differences in abundances of phenocryst minerals between mesas suggests that these mesas comprise several different lava flows. Individual flows can seldom be correlated across most of these mesas and the number of lava flows may differ between adjoining mesas. These basalts apparently comprise several lava flows that were erupted over a sufficiently long span of time for relief to be developed in the underlying tuffaceous sediment owing to erosion and (or) faulting. Differences in elevations of the older basalt mesas are attributed, in part, to confinement of basalt flows within northwest-trending fluvial channels and downwasting of adjacent, uncovered tuffaceous sediment between basalt eruptions. Accordingly, these basalt mesas likely represent an inversion of the topography that existed prior to eruption of the earliest basalt flows. That is, basalt that forms the topographically highest mesas was emplaced into early-formed channels; younger basalts of this group flowed into shallow arroyos cut into sediments not covered by older lavas. Although differences in elevations of some basalt mesas of this older group are attributed, in part, to erosion between eruptions of different lava flows, these mesa-forming basalts are also cut by northwest-trending faults at Buckaroo Pass in the northern part of the study area and east of Sage Hen Canyon in the southern part of the study area (fig. 2).

The younger group of basalts of this upper basalt unit show an increase in the number and thickness of lava flows from the Rocky Canyon area to the south. Probable vent areas for these lavas include a small butte about 1.5 mi north of Sage Hen Butte and perhaps Sage Hen Butte. The younger mesa-forming basalt is cut by north-north-east-trending faults along Guano Rim but is not cut by the northwest-trending faults (fig. 2).

Basalt Dikes (Tbi)

A 2-mi-long north-trending basalt dike in Sage Hen Canyon (fig. 2) has the characteristic diktytaxitic texture and low K_2O content of the mesa-forming basalts. This dike, dated at 12.8±1.3 Ma (J.E. Conrad, USGS, written commun., 1989), probably represents a feeder to a fissure vent system for the older group of mesa-forming basalt. It shows no displacement along the northwest-trending fault along Sage

Hen Canyon near Spaulding Reservoir. Smaller dikes, apparently equivalent to the dike mapped in Sage Hen Canyon, are also present in the northern part of the study area.

Undifferentiated Volcanic Rocks (Tv)

This unit includes generally thick andesitic to dacitic(?) lava flows that overlie tuffaceous sedimentary rocks and ash-flow tuff north of Buckaroo Pass (fig. 2). These rocks are probably late Miocene and appear to be derived from volcanic centers north of the study area.

Aeolian Sand (Qd)

Windblown sand deposits are present on or adjacent to basalt in the eastern part of Guano Valley at the base of Guano Rim scarp (fig. 2). These sands generally form sinusoidal dunes trending east-west. Locally developed cuspate dunes are convex to the south and indicate a northward migration direction of dunes.

Alluvium (Qa)

Alluvial deposits include accumulations of gravel, sand and silt along drainages and in Guano Valley. Silt and fine sand, probably carried onto the basalt mesas by wind, and locally-derived basalt debris are present in shallow depressions in the surfaces of the basalt mesas. These depressions, which intermittently pond with water, are as much as 1,500 ft across and about 10 to 25 ft deep.

Structure

Two episodes of faulting have displaced rocks in the study area. Older, northwest-trending faults were active in the middle and late(?) Miocene. Younger north-northeast-trending faults, related to formation of basins and ranges that dominate the present-day regional physiography, cut all volcanic strata in the study area.

The older, northwest-trending faults cut all volcanic rocks except for younger mesa-forming basalt. In part, movement along the northwest-trending faults appears to have been concurrent with eruption of mesa-forming basalt in the central part of the study area. Some of these mesa-forming basalts show displacement along northwest-trending faults; others appear to have flowed into shallow northwest-trending drainages that probably developed in grabens and are not offset. The youngest rocks cut by northwest-trending faults, the older mesa-forming basalt, are between about 13 to 9 Ma. The younger lavas of the upper basalt, however, show no displacement along the northwest-trending faults. Therefore, movement on the northwest-trending faults occurred prior to and probably during eruption of the older group of mesa forming basalt, which is between about 13 to 9 Ma, but ceased before eruption of the younger group of mesa-forming basalt at about 5 Ma. Minor tilting to the southwest and northeast is associated with the northwest-trending faults.

Movement along the younger north-northeast-trending faults has formed the 25-mi long scarp along Guano Rim (figs. 1 and 2). Normal displacement along this fault system has resulted in subsidence of Guano Valley relative to the range the east, and gentle tilting of this range to the east-southeast. In several places along this fault zone, narrow fault-bounded blocks about ½ mi wide have rotated downward to the north along curvilinear traces of faults that bound the south side of the blocks. These block rotations between subparallel faults occur where the main fault trace steps to the east. The east-stepping fault pattern suggests that the fault system along Guano Rim has a component of right-lateral displacement in addition to the dominantly vertical displacement. Tentative correlation of younger mesa-forming basalt in the Rocky Canyon area with basalt in Guano Valley indicates that about 500 ft of normal displacement has occurred along this fault zone since about 5 Ma. The conical shape of small alluvial fans along the Guano Rim scarp suggests that faulting has occurred in Quaternary time and perhaps is ongoing.

Alteration and Mineralization

Alteration of rocks in the study area is generally weak and localized. Weak iron-oxide staining is present at sites near Chimney Rock, and Miller (1988) reported local iron-staining and clay alteration adjacent to a dike about 2 mi north of Spaulding Reservoir. Miller (1988) also reported black glassy veins of unspecified mineralogy (goethite? and (or) manganese minerals?) north of Chimney Rock. Rounded clasts of silicified rock are present north of the study area at Buckaroo Pass and in the northwestern part of the study area in Guano Valley.

Manganiferous iron-oxide veins are present in upper Sage Hen Canyon. The manganiferous veins are dark gray to black, earthy, less than 3 in. thick, and continuous for only 5 to 15 ft. The veins cut tuffaceous sedimentary rocks in which a weak iron-oxide halo, about 150 ft long by 40 to 60 ft wide, developed. The larger veins trend mostly north, although smaller, thin (less than 1 in.), brittle to friable green and brown veins of amorphous material trend roughly east. The margins of the black veins commonly show stubby, radiating, granular aggregate forms, as much as 10 in. across and 2 in. thick, that probably formed by replacement.

Geochemical Studies

Introduction

A reconnaissance geochemical survey was conducted in the study area by the USGS in the summers of 1987 and 1988. The study consisted of collecting, analyzing, and evaluating rock, stream sediment, and heavy-mineral-concentrate samples. Minus-80 mesh (0.007 in.) stream sediments, nonmagnetic heavy-mineral concentrates of stream sediments, and rock samples were collected. Both a minus-80 mesh sample and a nonmagnetic heavy-mineral concentrate sample were collected from 49 sites. Eight rock samples were collected from five of those sites and 79 rock samples were collected from other sites. Most of the rock samples were taken from outcrops. The stream sediments from which the concentrates were derived were taken from active alluvium in stream channels.

The stream sediment and nonmagnetic heavy-mineral panned-concentrate samples (heavy-mineral concentrates) are collected primarily for their ability to reveal metal anomalies within drainage basins. Stream sediment samples represent a composite of the rock and soil exposed upstream from the sample site. The processing of heavy-mineral concentrates removes common rock-forming minerals and retains ore and ore-related minerals. The selective concentration of minerals permits determination of some elements that are not easily detected in bulk stream sediment samples.

The rock samples, nearly all of which appeared unaltered and unmineralized, were collected to determine if analyses might indicate mineralization. Some samples were collected to provide information on background concentrations of elements. In some cases, rock samples were collected along fractures to determine if anomalous concentrations of elements had been deposited there. Anomalous values were determined by statistical methods, by comparison of mineralized and altered samples with unaltered equivalent rocks, and by comparison of with published data for common rock types.

Sample Preparation

Stream sediment samples were sieved using 80-mesh stainless-steel sieves; the minus-80 mesh fraction was used for analysis. The heavy-mineral concentrate was obtained by panning minus-10-mesh (0.08 in.) stream sediment to remove most of the quartz, feldspar, organic material, and clay-size material. Immersion of this material in bromoform, a liquid having a specific gravity of 2.8, removed any light mineral grains remaining after panning. The resultant heavy-mineral concentrate was separated, using an electromagnet, into three fractions: a magnetic fraction, chiefly magnetite; an intermediate fraction consisting of common rock-forming minerals; and a nonmagnetic fraction composed predominantly of light-colored rock-forming accessory minerals and primary and secondary ore-forming and ore-related minerals. Using a microsplitter, the nonmagnetic fraction was split into two fractions. One of these fractions was analyzed and the other was visually examined with a binocular microscope. Rock samples were crushed and pulverized with ceramic plates to a grain size of less than 0.006 in.

Analytical Methods

The rock, stream sediment, and heavy-mineral-concentrate samples were analyzed for 35 elements (antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, chromium, cobalt, copper, gallium, germanium, gold, iron, lanthanum, lead, magnesium, manganese, molybdenum, nickel, niobium, phosphorus, sodium, scandium, silver, strontium, thorium, tin, titanium, tungsten, vanadium, yttrium, zinc, and zirconium) by a six-step, semiquantitative, direct-current arc emission spectrography method routinely used by the USGS (Grimes and Marranzino, 1968). Stream sediments were also analyzed by more sensitive techniques for certain elements of special interest. Antimony, arsenic, bismuth, cadmium, and zinc concentrations were determined by inductively coupled argon plasma-atomic emission spectroscopy (ICAP-AES) (Crock and others, 1987). Lower limits of determination for these elements are shown in parentheses as follows, in ppm: antimony (2), arsenic (5), bismuth (2), cadmium (0.1), and zinc (2). Mercury was analyzed by cold vapor atomic-absorption spectrometry (lower limit of determination, 20 ppb) (Crock and others, 1987).

Gold concentrations were determined in stream sediment samples and in 10 rock samples by flame atomic absorption (lower limit of determination, 50 ppb); 77 rock samples were analyzed for gold by flameless atomic absorption with a heated graphite atomizer (lower limit of determination, 2 ppb). Both methods are described in O'Leary and Meier (1986). Gold analyses obtained by these methods largely reflect the gold introduced into the rock by mineralization and not the total gold concentrations in the rock; the common rock-forming silicates, which may contain trace amounts of gold (less than 5 ppb), are not decomposed by the method used in gold analysis sample preparation.

Results and Interpretations

Anomalous values for several elements including silver, lead, barium, bismuth, and zinc are present in heavy-mineral concentrates from an area of about 2 mi^2 in the southeastern part of the study area, about 1 to 2 mi southwest of South Corral (fig. 2). The area is chiefly underlain by welded tuff cut by northwest-trending faults. Anomalous silver values (7 and 70 ppm Ag) are present in two of the heavy-mineral concentrates taken from adjacent streams. The sample with the higher silver value also contains anomalous values of lead (1,500 ppm), barium (2,000 ppm), bismuth (70 ppm), and zinc (700 ppm). Two concentrate samples collected upstream from the site with the 70 ppm silver value contain 200 and 300 ppm lead but no other elements in anomalous concentrations; however, samples of welded tuff from these same two sites contain moderately anomalous concentrations of copper (100 and 150 ppm). Anomalous amounts of barium (3,000 to more than 10,000 ppm) are present in three other concentrate samples from this area and are attributed to small amounts of barite in the concentrates. The concentrates from this area also contain pyrite; the largest amount of pyrite, about 10 percent of the concentrate, is present in the concentrate with the 70 ppm silver value. The abundance of silver, lead, and zinc in concentrate samples suggests these elements are most likely present as impurities in galena. Although no galena was observed in the concentrates, it could be present as mineral grains included in pyrite and (or) as individual grains that are altered to anglesite, a common alteration mineral after galena in surficial environments. Anglesite is colorless or weakly colored and could have been easily overlooked during microscopic examination of the concentrates.

The source of barite and pyrite and associated geochemical anomalies in the southeastern part of the study area is enigmatic because no visibly altered or mineralized rock was observed in nearby areas. The presence of barite and the angular, faceted morphology of pyrite grains suggest that these minerals are derived locally and most likely have not been transported from distant sources into the study area. These minerals may have been eroded from fractures or cavities in tuff along northwest-trending faults that cut this area but iron-staining, a characteristic result of oxidation of iron sulfide, is absent. The small amount of pyrite found, however, suggests the presence of only a small amount of pyrite in the area, and therefore a noticeable amount of iron staining may not be expected.

In the northwestern part of the study area, where traces of alluvial gold are present (Miller, 1988), no significantly altered rock was observed in outcrop. The alluvial gold may possibly be derived from buried mineralized rock or, alternatively, may be derived from mineralized rock outside the study area and was transported into the study area by fluvial processes. In the latter interpretation, concentration of gold in alluvium occurred during erosion and redeposition of the tuffaceous sediment. Analyses of the finer grained tuffaceous sediments shows no geochemical anomalies but rounded, silicified cobbles, apparently derived from tuffaceous sedimentary rocks, were found in the northern and northwestern parts of the study area. The presence of altered clasts, and notably the rounded shape of silicified clasts, suggest that the gold in this area may have been derived from mineralized rock located some distance from the study area.

Nonmagnetic heavy-mineral-concentrate samples from two sites along Sage Hen Creek near the southern boundary of the study area contain high values of lead (2,000 and 50,000 ppm). The sample with the highest lead also contains antimony, less than 200 ppm. Both the lead and antimony can be attributed to bullet fragments or lead shot, which commonly contain antimony as a hardening agent. A metal particle from the sample with the highest lead value was determined by x-ray analysis to be a lead artifact. Although most of the artifact was removed from the sample prior to analysis, oxidized margins of the artifact that were not extracted from the sample most likely contributed lead and antimony to the sample that was analyzed.

Anomalous concentrations of several elements are present in samples of thin veins collected in Sage Hen Canyon. Most of the veins are dark gray and oxidized. Samples generally contain abundant iron oxide and three samples contain 5,000 ppm or more manganese. Anomalous arsenic is also present in most of these samples; the higher arsenic values (28 to 67 ppm) are in samples with high amounts of iron (5 to 15 percent), and the lower arsenic values are in samples with high amounts of manganese (greater than 5,000 ppm). Several of these samples also contain anomalous amounts of cadmium (1.7 to 6.5 ppm) and molybdenum (as much as 20 ppm). The samples with high manganese values also contain anomalous amounts of antimony (16 and 17 ppm), barium (greater than 5,000 ppm), bismuth (4 ppm), cobalt (150 ppm in one sample), mercury (0.18 ppm) and zinc (122 and 123 ppm). These anomalous elements were probably enriched by coprecipitation and scavenging (adsorption) of the elements by the iron and (or) manganese oxides (Chao and Theobald, 1976; Levinson, 1974, p. 134–138). As such, the anomalies may be unrelated to mineral deposits, and instead are probably the result of enrichment of the elements over background concentrations from the weathering of unmineralized rock. No gold was detected in any of these vein samples at a lower limit of determination of 2 ppb. Although black glassy veins from northwest of Chimney Rock were not analyzed for manganese, they contain weakly anomalous concentrations of barium, molybdenum, and arsenic (see "Identified Resources"), and they may be similar to the manganiferous veins in Sage Hen Canyon.

Geophysical Studies

Gamma-ray Survey

The aerial gamma-ray data were compiled by Geodata International, Inc. (1980) for the National Uranium Resource Evaluation (NURE) program of the U.S. Department of Energy. The survey was flown in east-west lines with 6-mi spacing at flight altitudes ranging from 200 to 500 ft above the ground. The coverage in the study area consists of 4 east-west flightlines totaling about 20 mi. Recordings were made of gamma-ray flux from radioactive isotopes of uranium, thorium, and potassium. Radioactivity count rates generally were low over the andesite exposed in the southwestern part of the study area and the mesa-forming basalt. Radioactivity count rates exceeded the mean background level over rhyolitic rocks in the study area, including tuffaceous sedimentary rocks and ash-flow tuff. However, these count rates are attributed to generally higher uranium and thorium concentrations in the rhyolite compared to average crustal rocks and to the basalt and andesite in other parts of the study area. No locality was identified where the concentration of either uranium or thorium is high enough to indicate the presence of uranium or thorium resources.

Gravity Survey

Gravity data were previously available at two sites along the edge of and about 1 mi south of the study area (National Geophysical Data Center, 1984). In 1986, the USGS established 6 gravity stations along the margins of the study area and 25 stations within 5 mi of the study area (Plouff, 1987). A gravity-anomaly map shows that gravity anomalies interpolated within the study area increase to the northwest by about 12 milligals in 10 mi. The source of the gravity gradient is probably a contrast in density between rock masses buried deeply beneath the surface. A local small-amplitude gravity high is located near the west corner of the study area.

Aeromagnetic Survey

A regional aeromagnetic survey was flown over the study area at a constant barometric elevation of 9,000 ft above sea level with east-west flightline spacings of about 2 mi (U.S. Geological Survey, 1972). An aeromagnetic low with two minima covers most of the study area. The shape and location of the aeromagnetic low correlate with areas underlain by andesite and ash-flow tuff. Therefore, these rocks probably erupted and cooled at a time when the Earth's magnetic field was reversed. The pattern of the magnetic low is interrupted by a north-trending magnetic high through the central part of the study area over outcrops of normally magnetized mesa-forming basalt.

Implications for Mineral Resource Potential

The geophysical data provide no constraints on the distribution of altered or mineralized rock in the study area. Altered areas are typically only several feet wide in the study area; these relatively small features are not detected with geophysical data collected on widely spaced flightlines or from widely distributed stations. No extensions of known sites of alteration were found.

MINERAL RESOURCE POTENTIAL

The mineral resource potential of the Spaulding Wilderness Study Area was assessed on the basis of geologic investigations, geochemical and geophysical studies, and a study of prospects and claims in the area of reported mineral occurrences and deposits in the region. The northwestern and southeastern parts of the study area have low potential for epithermal gold and silver resources, with a certainty level of B. This assessment is based on the presence of localized gold or altered areas and (or) the presence of geochemical anomalies associated with precious-metal mineralization. Geochemical anomalies in silver, lead, zinc, bismuth, and the ore-related minerals barite and pyrite are present in nonmagnetic heavy-mineral concentrates from the southeastern part of the study area, and trace amounts of free gold are present in alluvial sand and gravel samples from the northwestern part of the study area. The source of these geochemical and mineral anomalies may differ for the northwestern and southeastern parts of the study area.

The presence of rounded clasts of silicified rock in the northwestern part of the study area suggests that the source of gold in this area may be detrital clasts of altered and mineralized rock. No similar rocks were found in outcrop and the rounding of these clasts suggests significant transport distances. The altered clasts probably were eroded from tuffaceous sedimentary rocks, which had a provenance outside the study area. Most, if not all, of the study area was at one time covered by tuffaceous sediment. Hence, the geochemical anomalies and traces of alluvial gold may be related to sources outside the study area. Scattered weak alteration zones suggest that minor hydrothermal alteration has affected parts of this area.

In the southeastern part of the study area, the presence in stream-sediment samples of faceted ore-related minerals showing little evidence of abrasion suggests that hydrothermal alteration has affected this part of the study area and that a local bedrock source is likely. Alternatively, the pyrite and barite present in the southeastern part of the study area may represent reworked lag deposits that remained after erosion of tuffaceous sediment off the welded tuff and were incorporated into present-day alluvium. This latter explanation is consistent with the general lack of alteration in exposed rocks in the area and the dispersed, low-level geochemical anomalies indicated by analysis of alluvial material, but is difficult to reconcile with the angular shape of crystal fragments of relatively soft minerals, such as barite, that were found in stream sediment samples.

The geochemical anomalies of elements such as mercury, arsenic, antimony, lead, copper, zinc, bismuth, and cadmium do not indicate potential resources for deposits of these elements. Concentrations of these elements are far below economic levels, and they are viewed as accessory constituents of an element suite related to epithermal precious-metal mineralization.

Tuffaceous rocks that pass nominal tests for use as pozzolan, which could possibly be used as additives to cement, are found in the northern part of the study area. These rocks, however, would require detailed testing for compatibility with various cements. In addition, considering that the value of pozzolan depends largely on proximity to market and that similar rocks are widespread throughout the western United States, it is unlikely that these rocks will ever be mined. Perlite is present in small amounts in and near the study area but is of poor quality. The stone in the study area has no special aesthetic characteristics or physical properties that make it particularly desirable for decorative or construction uses. The pozzolanic rocks, perlite, and stone are regarded as occurrences only and have no resource potential.

There is low oil and gas potential in the study area (Fouch, 1982, 1983). The tuffaceous sedimentary rocks, the only likely source rock for hydrocarbons, do not contain significant amounts of organic material. There are no geologic indications of oil and gas or structural traps for hydrocarbon accumulation in or around the study area; hence, the assessment of low potential may be too high. If oil and gas are present at depth in the area, then they are buried beneath the volcanic section and could only be found with detailed geophysical surveys and drilling. The certainty of assessment, therefore, is B.

The study area has no geothermal energy potential, certainty level D (Muffler, 1979). No young volcanic centers are located in the area. The youngest volcanic rocks in the study area are the younger mesa-forming basalts, which are about 5 Ma. No fossil or active hot springs are present in the area.

The study area has no uranium or thorium mineral resource potential, certainty level D. Aerial gamma-ray surveys indicate slightly high amounts of uranium and thorium in rhyolitic rocks in the study area, but these levels are typical of rhyolitic rocks in the Basin and Range province. Field scintillometer readings and laboratory checks for radioactivity of heavy mineral fractions of alluvial material showed no anomalous readings.

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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 t 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, an (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 not 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.

<table>
<tr><th rowspan="5">LEVEL OF RESOURCE POTENTIAL →</th><th>A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td rowspan="4">U/A

UNKNOWN POTENTIAL</td><td>H/B
HIGH POTENTIAL</td><td>H/C
HIGH POTENTIAL</td><td>H/D
HIGH POTENTIAL</td></tr>
<tr><td>M/B
MODERATE POTENTIAL</td><td>M/C
MODERATE POTENTIAL</td><td>M/D
MODERATE POTENTIAL</td></tr>
<tr><td rowspan="2">L/B
LOW POTENTIAL</td><td rowspan="2">L/C
LOW POTENTIAL</td><td>L/D
LOW POTENTIAL</td></tr>
<tr><td>N/D
NO POTENTIAL</td></tr>
</table>

LEVEL OF CERTAINTY →

Abstracted with minor modifications from:

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

RESOURCE/RESERVE CLASSIFICATION

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

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

GEOLOGIC TIME CHART

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

EON	ERA	PERIOD		EPOCH	AGE ESTIMATES OF BOUNDARIES IN MILLION YEARS (Ma)
Phanerozoic	Cenozoic	Quaternary		Holocene	0.010
				Pleistocene	1.7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late	96
				Early	138
		Jurassic		Late 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.

Mineral Resources of Wilderness Study Areas: South-Central Oregon

This volume was published as separate chapters A–E

U.S. GEOLOGICAL SURVEY BULLETIN 1738

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

CONTENTS

[Letters designate the separately published chapters]

*U.S. GOVERNMENT PRINTING OFFICE: 1995-683-048/10015

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Periodicals

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Preliminary Determination of Epicenters (issued monthly).

Technical Books and Reports

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

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

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

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

Maps

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

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

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