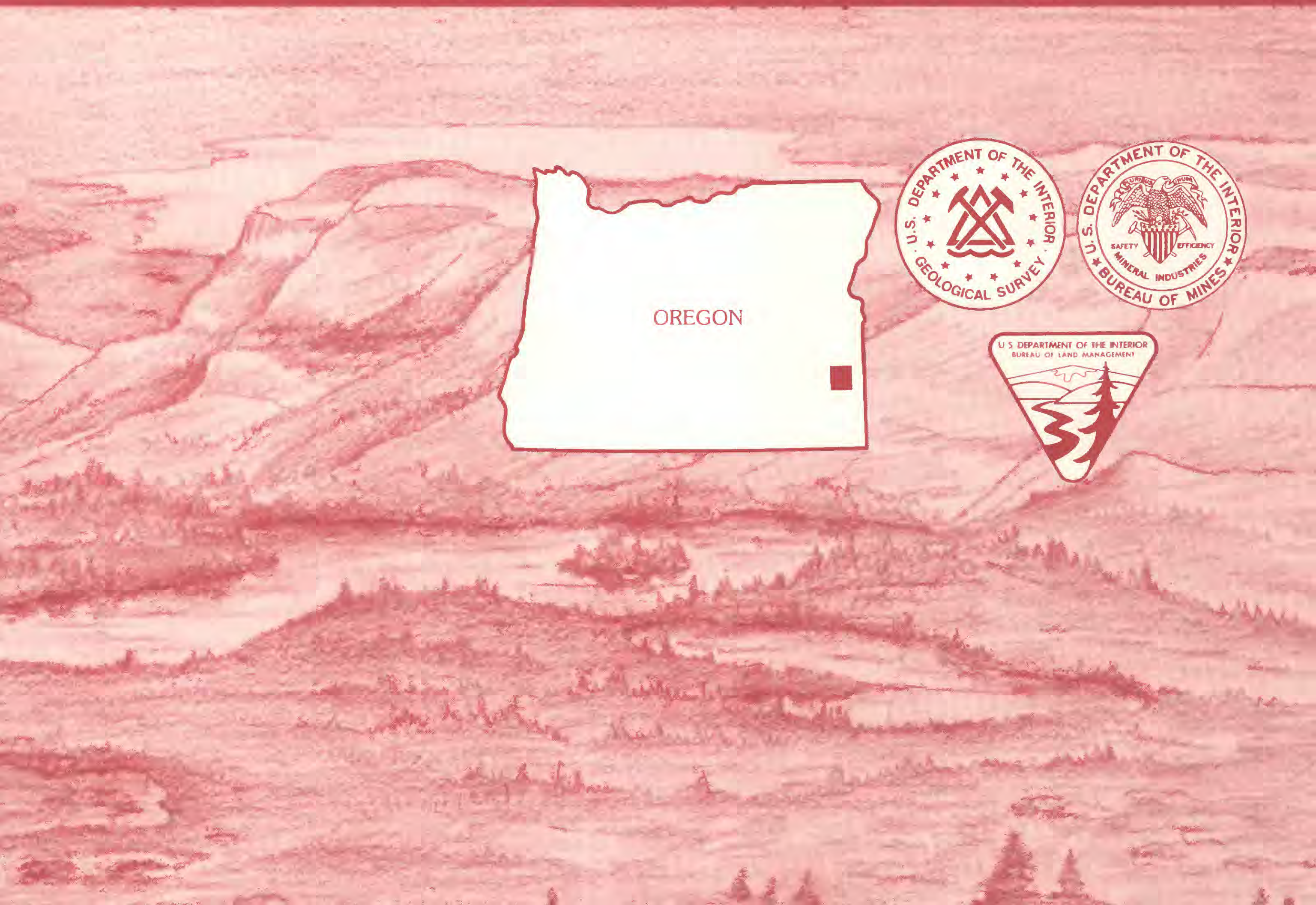
Mineral Resources of the Upper Leslie Gulch and Slocum Creek Wilderness Study Areas, Malheur County, Oregon

U.S. GEOLOGICAL SURVEY BULLETIN 1741-D



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Chapter D

Mineral Resources of the Upper Leslie Gulch and Slocum Creek Wilderness Study Areas, Malheur County, Oregon

By DEAN B. VANDER MEULEN, ANDREW GRISCOM, and HARLEY D. KING
U.S. Geological Survey

JOHN R. BENHAM
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1741

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
EAST-CENTRAL OREGON

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 Study Area

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Upper Leslie Gulch and Slocum Creek Wilderness Study Areas (OR–003–074 and OR–003–075), Malheur County, Oregon.

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FIGURES

Mineral Resources of the Upper Leslie Gulch and Slocum Creek Wilderness Study Areas, Malheur County, Oregon

By Dean B. Vander Meulen, Andrew Griscom, *and* Harley D. King
U.S. Geological Survey

John R. Benham
U.S. Bureau of Mines

SUMMARY

Abstract

At the request of the U.S. Bureau of Land Management, the U.S. Geological Survey and the U.S. Bureau of Mines conducted field studies of 3,000 acres and 7,600 acres, respectively, in the contiguous Upper Leslie Gulch and Slocum Creek Wilderness Study Areas (OR-003-074 and OR-003-075); the areas are located east of the Owyhee Reservoir in eastern Oregon. In this report, the study areas are referred to, individually or collectively, as the "wilderness study area" or simply the "study area." Fieldwork was conducted by the U.S. Geological Survey and the U.S. Bureau of Mines during 1987 to evaluate the identified mineral resources (known) and the mineral resource potential (undiscovered) of the study area.

No energy or mineral resources were identified in either study area. Areas underlain by peralkaline rhyolite ash-flow and air-fall tuff and by intrusions associated with the Mahogany Mountain caldera have moderate potential for uranium and thorium resources and low potential for zinc resources. These tuffs are exposed in the west-central and eastern parts of the study area. All of the tuffs and rhyolite intrusions exposed in the study area have low potential for lithium resources. Rhyolite dikes and plugs that intrude both study areas have moderate potential for gold, silver, mercury, and zinc resources. North-trending fault zones within and adjacent to the Slocum Creek Wilderness Study Area have moderate potential for geothermal resources. The Upper Leslie Gulch Wilderness Study Area has unknown potential for geothermal resources. The Upper Leslie Gulch and Slocum Creek Study Areas have no potential for oil and gas resources.

Manuscript approved for publication, May 26, 1989.

Character and Setting

The Upper Leslie Gulch and Slocum Creek Wilderness Study Areas are located within the Mahogany Mountain caldera approximately 50 mi west of Boise, Idaho, and 25 mi north of Jordan Valley, Oregon (fig. 1). The study area includes the southeastern part of the caldera-collapse structure north of Mahogany Mountain. This part of the caldera forms a topographic low characterized by north- and northwest-trending ridges and intervening, deeply eroded canyons.

The study area is underlain by a thick sequence of middle Miocene intracaldera ash-flow and air-fall tuff. Time spanned by the middle Miocene is herein considered to extend from approximately 11.2 to 16.6 million years before present, or Ma (see appendixes for geologic time chart). The intracaldera ash-flow and air-fall tuff erupted from a vent located near the center of the Mahogany Mountain caldera, contemporaneously with the collapse of the caldera. These caldera-forming tuff units (Tlga and Tlgi, fig. 2) are the oldest rocks exposed in the study area. The central-vent structure was subsequently filled by intrusions of rhyolite breccia and dikes (Trvi, fig. 2) and is presently exposed in the north-central part of the study area.

The central and eastern parts of the study area were uplifted, domed, and faulted by post-caldera resurgent activity. Two post-caldera ash-flow tuff units unrelated to the Mahogany Mountain caldera ponded in the caldera following resurgent activity. A north-trending graben cuts the resurgent dome near the center of the study area and is filled with post-caldera tuff (Tsc and Tbc, fig. 2). Basalt dikes, plugs, and north-trending rhyolite dikes, Tbi and Trp

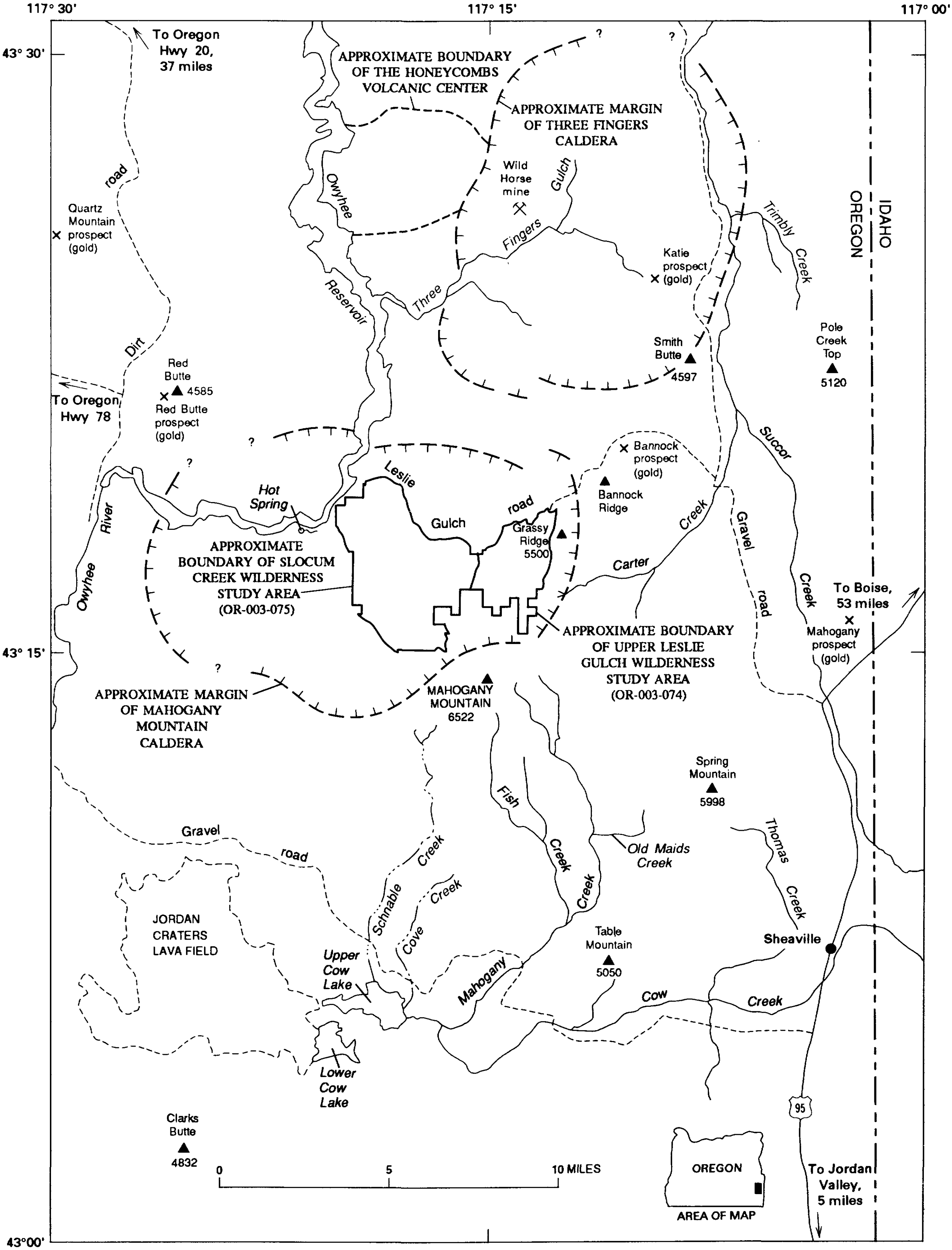


Figure 1. Index map showing location of Upper Leslie Gulch and Slocum Creek Wilderness Study Areas, Malheur County, Oregon. Caldera margins and nearby prospects also shown; inferred location of caldera margins shown by queries.

respectively, as shown on figure 2, intrude the caldera-forming and post-caldera tuffs and are the youngest volcanic rocks in the study area.

Identified Resources

No mines, claims, or prospects were found in either study area. There are no identified mineral or energy resources within or adjacent to the study areas. Sand and gravel deposits along drainages within the study areas do not constitute resources because similar deposits are more accessible and closer to existing markets. Welded parts of the caldera-forming tuff exposed within the study areas are suitable for construction purposes; however, because similar tuff elsewhere is more accessible and closer to existing markets, this tuff does not constitute a resource.

Mineral Resource Potential of the Upper Leslie Gulch Wilderness Study Area

Parts of the Upper Leslie Gulch Wilderness Study Area underlain by caldera-forming rhyolite ash-flow and air-fall tuff associated with the Mahogany Mountain caldera have moderate potential for uranium and thorium resources. The resource potential rating is based on anomalous concentrations in four rock samples and on highly anomalous aerial gamma-ray values for uranium and thorium reported over the study area.

Six samples of caldera-forming and post-caldera tuff collected 2 mi north of the study area contain high concentrations of lithium. One sample of a rhyolite dike collected along the western boundary of the study area also contains anomalous concentrations of lithium. All tuffs in the study area have low potential for stratiform lithium resources.

Anomalous concentrations of zinc were detected in 43 samples of caldera-forming rhyolite tuff and 10 samples of vent rhyolite breccia. Approximately one-third of these samples were collected within the study area and the remaining samples were collected north and west of the study area. Therefore, parts of the study area underlain by caldera-forming tuff have low potential for zinc in volcanogenic disseminated deposits.

Rhyolite dikes that intrude the western part of the Upper Leslie Gulch Wilderness Study Area are locally brecciated and cut by quartz veins. Chemical analyses of the dikes indicate that the brecciated rhyolite contains anomalous concentrations of mercury, zinc, and arsenic. Although no gold and silver were detected in the samples analyzed, mercury and arsenic are pathfinders for these resources. Gold and silver resources have been discovered in similar rhyolite intrusions 6 mi north of the study area. Therefore, the rhyolite dikes have moderate potential for gold, silver, mercury, and zinc resources.

Several thermal springs and wells are located approximately 17 mi north of the study area. The springs are underlain by a thermal water reservoir less than 3,280 ft below the surface. A thermal spring approximately 6 mi west of the study area (fig. 1) issues from a north-trending normal fault. No north-trending fault zones were mapped in the study area, although similar faults may be buried by alluvium along the length of Leslie Gulch. Consequently, the study area has unknown potential for geothermal energy.

Parts of the caldera-forming and post-caldera ash-flow and air-fall tuff (fig. 2) that underlies most of the study area are suitable for construction purposes; however, similar deposits elsewhere are more accessible and closer to existing markets.

There is no potential for oil and gas resources in the Upper Leslie Gulch Wilderness Study Area.

Mineral Resource Potential of the Slocum Creek Wilderness Study Area

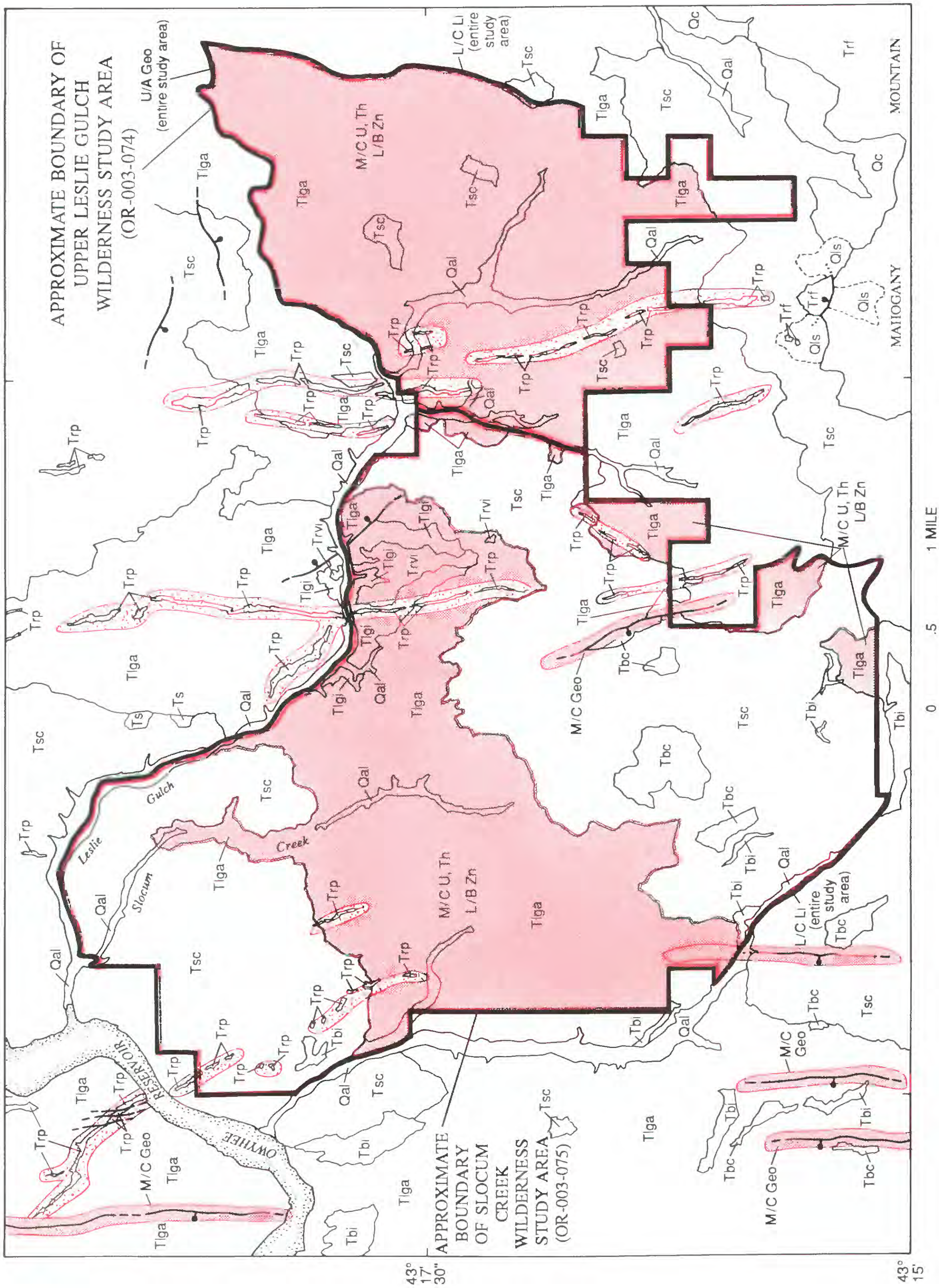
Parts of the study area underlain by caldera-forming rhyolite ash-flow tuff, air-fall tuff, and rhyolite intrusions have moderate potential for uranium and thorium resources on the basis of anomalous concentrations of uranium and thorium contained in four samples of tuff and two samples of rhyolite intrusions. The tuffs and intrusions are exposed over approximately one-third of the study area.

Six samples of caldera-forming and post-caldera tuff collected 4 mi northeast of the study area contain high concentrations of lithium. Samples of rhyolite dikes collected in the western and northeastern parts of the study area also contain anomalous concentrations of lithium. All tuffs in the study area have low potential for lithium resources in stratiform deposits.

Anomalous concentrations of zinc were detected in 43 samples of caldera-forming rhyolite tuff and 10 samples of vent rhyolite breccia. Approximately two-thirds of these samples were collected within the study area and the remaining samples were collected north and east of the study area. Therefore, parts of the study area underlain by caldera-forming tuff and the vent breccia have low potential for zinc in volcanogenic disseminated deposits.

Rhyolite dikes that intrude the eastern and northwestern parts of the Slocum Creek Wilderness Study Area are locally brecciated and cut by quartz veins. Chemical analyses of the dikes indicate that the brecciated rhyolite contains anomalous concentrations of mercury, zinc, and arsenic. Although no gold and silver were detected in the samples analyzed, mercury and arsenic are pathfinders for these resources. Gold and silver resources have been discovered in similar rhyolite intrusions 10 mi northeast of the study area. Therefore, the rhyolite dikes have moderate potential for gold, silver, mercury, and zinc resources.

Several thermal springs and wells are located approximately 16 mi north of the study area. The springs are underlain by a thermal water reservoir less than 3,280 ft


APPROXIMATE BOUNDARY OF UPPER LESLIE GULCH WILDERNESS STUDY AREA (OR-003-074)
U/A Geo (entire study area)
L/C Li (entire study area)
M/C U, Th L/B Zn
APPROXIMATE BOUNDARY OF SLOCUM CREEK WILDERNESS STUDY AREA (OR-003-075)
M/C Geo
MAHOGANY MOUNTAIN
OWYHEE RESERVOIR
Leslie Gulch
Slocum Creek
117°20'
117°15'
43° 17' 30"
43° 15'
0 .5 1 MILE

below the surface. A thermal spring about 2 mi west of the study area (fig. 1) issues from a north-trending normal fault. Similar fault zones that cut the study area may be associated with geothermal waters at depth. Therefore, north-trending fault zones within and adjacent to the study area have moderate potential for geothermal energy.

Parts of the caldera-forming and post-caldera ash-flow and air-fall tuff (fig. 2) that underlies most of the study area are suitable for construction purposes; however, similar deposits elsewhere are more accessible and closer to existing markets.

There is no potential for oil and gas resources in the Slocum Creek Wilderness Study Area.

INTRODUCTION

These mineral surveys were requested by the U.S. Bureau of Land Management and are a joint effort by the U.S. Geological Survey and 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. Mineral assessment methodology and terminology as they apply to these surveys were discussed by Goudarzi (1984). See appendixes for definition of levels of mineral resource potential, certainty of assessment, and resource/reserve classification.

Area Description

The contiguous Upper Leslie Gulch and the Slocum Creek Wilderness Study Areas encompass 10,600 acres in the northern Basin and Range physiographic province of eastern Oregon. The study area is approximately 3 mi north of Mahogany Mountain and 9 mi west of the Idaho stateline (fig. 1). The area is accessible from U.S. Highway 95 via an improved gravel road that parallels Succor Creek and by the Leslie Gulch road (fig. 1) that parallels the northern border of both study areas. Maximum elevation in the study area is approximately 5,500 ft above sea level along the west slope of Grassy Ridge (fig. 1); minimum elevation is about 2,750 ft at the mouth of Leslie Gulch.

EXPLANATION

Area having moderate resource potential (M)

Area having moderate mineral resource potential (M), certainty level B, for Au, Ag, Hg, and Zn

Area having low (L) mineral resource potential

Levels of certainty of assessment

A Data not adequate for determination of potential
B Data only suggest level of potential
C Data give good indication of level of potential

Commodities

Ag Silver
Au Gold
Geo Geothermal energy
Hg Mercury
Li Lithium
Th Thorium
U Uranium

Geologic map units

Qal Alluvium (Quaternary)
Qc Colluvium deposits (Quaternary)
Qls Landslide deposits (Quaternary)
Ts Sedimentary rocks (Tertiary)
Trp Rhyolite porphyry (Tertiary)
Tbi Basalt intrusions (Tertiary)
Tbc Tuff of Birch Creek (Tertiary)
Tsc Tuff of Spring Creek (Tertiary)
Trvi Rhyolite vent intrusion (Tertiary)
Tlga Leslie Gulch Tuff; air-fall facies (Tertiary)
Tlgi Leslie Gulch Tuff; intracaldera facies (Tertiary)
Trf Rhyolite flows (Tertiary)

Contact—Dashed where approximately located

Fault—Dashed where inferred; dotted where concealed; ball and bar on downthrown side

Figure 2. Mineral resource potential and generalized geology of Upper Leslie Gulch and Slocum Creek Wilderness Study Areas, Malheur County, Oregon.

The area is drained by several small creeks that flow north and northwest into Leslie Gulch and the Owyhee Reservoir. The climate is semiarid and the average annual precipitation is 10 in. or less. Vegetation is sparse and includes sagebrush and grasses at all elevations. Juniper trees grow along creek bottoms and in protected gulches.

Previous and Present Investigations

Previous geologic investigations that include the study area are a reconnaissance geologic map of the Owyhee region by Kittleman and others (1967) and an aeromagnetic survey by Boler (1979). An airborne radiometric and aeromagnetic survey of the study area was conducted by Geometrics, Inc. (1979) during the U.S. Department of Energy's National Uranium Resource Evaluation (NURE) program. A preliminary evaluation of the mineral resources of the Slocum Creek Wilderness Study Area was made by the Oregon Department of Geology and Mineral Industries (DOGAMI) (Gray and others, 1983).

The U.S. Geological Survey mapped the geology of the study area in the summers of 1984–85 and 1987 (Vander Meulen and others, 1987a, d). A caldera collapse structure, referred to as the Mahogany Mountain caldera, which underlies both study areas (fig. 1) was first recognized in 1984 (Rytuba and others, 1985). Field investigations during 1984 and 1985 involved detailed geologic mapping at scales of 1:24,000 and 1:18,000 of the resurgent dome and vent complex located near the center of the caldera (Vander Meulen, 1988; Vander Meulen, 1989). The U.S. Geological Survey conducted a combined geologic, geochemical, and geophysical survey of the Upper Leslie Gulch and Slocum Creek Wilderness Study Areas during 1987. Field investigations focused on correlating geochemical and geophysical anomalies with rock units and geologic structures. Rock, stream-sediment, and nonmagnetic heavy-mineral concentrates of stream-sediment samples were analyzed for 31 elements by semiquantitative emission spectrography. Atomic absorption was used to analyze for gold and mercury, and the presence of uranium was determined by ultraviolet fluorescence. Earlier geophysical gravity data were supplemented by data from additional gravity stations within and near the study area (Plouff, 1987).

The U.S. Bureau of Mines investigation consisted of prefield and field studies (Benham, 1988). During the prefield study, mining-related data were examined. These data were gathered from the libraries and records of the U.S. Bureau of Mines and the U.S. Bureau of Land Management; state, county, and other government agencies; and private sources. Field studies included a ground reconnaissance to search for evidence of possible mineralized areas and unrecorded mining activity. Additional information is available from the U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Avenue, Spokane, WA 99202.

APPRAISAL OF IDENTIFIED RESOURCES

By John R. Benham
U.S. Bureau of Mines

Mines, Prospects, Claims, and Mineralized Areas

Gold placer claims were located south of Leslie Gulch (fig. 1) around 1906 (Scott, 1986). Other than the placer claims, no records of mining or mineral exploration were found in the literature, nor was any evidence of exploration or mining-related activity discovered during surface and aerial reconnaissance of the study area.

The nearest active mine is the Wild Horse mine located approximately 9 mi north of the study area (Scott, 1986, p. 12). Picture jasper is produced from this mine on a seasonal basis. A zeolite mineral (clinoptilolite) and bentonite are currently being mined 18 mi northeast of the study area by Teague Mineral Products of Adrian. Presently, the nearest metal producing mine, the DeLamar mine, is 26 mi southeast of the study area. At this mine, gold and silver are produced from epithermal deposits in veins, fracture fillings, and veinlets within porphyritic rhyolite.

Presently, there are no mining districts in or near the study area. The nearest district in Oregon is the Harper District where diatomite was produced from 1910 to 1975 (Moore, 1937, p. 65–71). It is located approximately 40 mi northwest of the study area.

According to current U.S. Bureau of Land Management plats, there are no geothermal or other energy leases or lease applications within the study area. No hot springs or other geothermal phenomena were seen within the study area during field investigations.

Appraisal of Mineral Resources

There are no mineral or energy resources in or adjacent to the Upper Leslie Gulch and Slocum Creek Wilderness Study Areas. Twenty-three rock samples collected from the study area were analyzed for 18 elements. Examination of the data by statistical methods revealed no unusual concentrations of elements defined as anomalous or economic.

During field reconnaissance, portable gamma-ray detecting scintillometers were carried and monitored to detect anomalous radioactivity. No anomalous radioactivity was detected in the study area. A detailed radiometric survey of the study area may be warranted if a national shortage of uranium were to occur.

Because the study area lies near producing zeolite mines, 10 samples were screened for cation exchange-molecular sieve properties using a test described by Helfferich (1964). The results were negative and no further testing was done. Also, most of the tuff in the study areas is indurated, unlike the disaggregated or unconsolidated tuffaceous material that is commonly the source of commercial zeolite deposits. During the upper Miocene and Pliocene, the depositional environment of the region was favorable for the accumulation of diatomite; however, careful field examination did not reveal any diatomite deposits in the study area. Sand and gravel are not a resource because similar deposits elsewhere are more accessible and closer to existing markets.

The study area lies 40 mi south of the Vale Known Geothermal Resource Area (KGRA) (Couch and Baker, 1977) between two blocks of land classified by the U.S. Geological Survey as valuable for geothermal steam and associated geothermal resources (Muffler, 1979). No hot springs or other geothermal phenomena were observed within the study area.

An estimated 3,000 acres of stone (welded tuff) is present in the study area. The rock could be used locally for crushed stone applications. The stone is not considered a resource because similar deposits elsewhere are more accessible and closer to existing markets.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Dean B. Vander Meulen, Andrew Griscom, *and* Harley D. King
U.S. Geological Survey

Geology

Caldera Evolution

The Upper Leslie Gulch and Slocum Creek Wilderness Study Areas lie along the northern boundary of the Basin and Range physiographic province, a region characterized by east-west extensional tectonism. The study area is located within the eastern part of the Mahogany Mountain caldera (fig. 1), a collapse structure that resulted from the eruption of voluminous ash-flow and air-fall tuffs. The caldera is expressed as a 8- by 12-mi elliptical depression. Erosion removed the original caldera structural wall and left a marginal high topographic wall encircling most of the caldera moat. The caldera margin (fig. 1) parallels the base of the topographic wall, which is well exposed along the north escarpment of Mahogany Mountain; the north topographic wall coincides with an escarpment 1.9 mi north of Leslie Gulch (fig. 1). Several mineral exploration companies are currently prospecting for disseminated gold and silver deposits along the margins of the Mahogany Mountain and Three Fingers calderas (Vander Meulen and others, 1989; fig. 1). The east-central part of the Mahogany Mountain caldera was uplifted during post-collapse resurgence, a result of renewed rise of magma (Lipman, 1984). Uplift of the caldera floor domed and faulted intracaldera rocks and formed a topographic high near the center of the caldera. The resurgent dome includes most of the central and eastern parts of the study area. A north-trending graben that cuts the central part of the study area probably formed in response to extensional stresses across the crest of the resurgent dome. The faults that bound the graben are buried by post-caldera tuff.

The topographic margin of the caldera is, in part, controlled by north-trending normal faults; this indicates that caldera collapse may have occurred along these preexisting faults. North-trending normal faults that cut the west side of the map area (fig. 2) partly define the east side of a large north-trending graben. Most of the western margin of the caldera is buried by post-caldera basalt flows, sedimentary rocks, and debris slides; this suggests subsidence along these faults probably continued after caldera collapse.

The volcanic and structural evolution of the Mahogany Mountain caldera generally parallels the stages of caldera evolution proposed by Smith and Bailey (1968). Three episodes of silicic volcanism are associated with the formation of this caldera. They are (1) an extensive precaldera dome and multiflow rhyolite complex at Mahogany Mountain, (2) rhyolite ash-flow and air-fall tuffs that erupted concurrently with the collapse of the caldera, and (3) post-caldera rhyolite dikes and plugs that intrude intracaldera tuffs. Mineralization in the study area was associated with the last two stages of volcanic activity.

The precaldera rhyolite dome and flow complex located 0.5 mi south of the study area was originally mapped as the Jump Creek Rhyolite by Kittleman (1973), but our current mapping has demonstrated that those silicic rocks are older than the type area of the Jump Creek Rhyolite and are here informally named the rhyolite of Mahogany Mountain (Trf, fig. 2). The northern part of the dome and flow complex subsided with the formation of the Mahogany Mountain caldera. Remnants of the rhyolite complex that did not subside include the northern scarp of Mahogany Mountain and the southern topographic wall that represents the caldera margin.

Rhyolite ash-flow and air-fall tuffs erupted concurrently with the collapse of the Mahogany Mountain caldera and filled the resulting depression with an estimated 2,600 ft of intracaldera tuff (Vander Meulen, 1988). The intracaldera tuff units represent the second stage of silicic volcanism and are the oldest rocks exposed in the study area. The intracaldera tuff units are part of the Leslie Gulch Ash-Flow Tuff Member of the Sucker Creek Formation of Kittleman and others (1965) (see also, Kittleman, 1973). A potassium-argon age obtained from the tuff is 15.5±0.5 Ma (Vander Meulen and others, 1987d). All ages reported in this investigation were obtained from sanidine mineral separates. Major- and trace-element analyses (Vander Meulen, 1988) indicate that the intracaldera tuffs are weakly peralkaline comendites.

Silicic volcanism associated with the Mahogany Mountain caldera concluded with rhyolite intrusions. Two north-striking and one northwest-trending rhyolite dike systems intrude the floor of the caldera. The north-striking rhyolite dikes cut across the width of the caldera and are exposed in the western part of the Upper Leslie Gulch Wilderness Study Area and in the eastern part of the Slocum Creek Wilderness Study Area (fig. 2). The rhyolite dikes parallel both sides of the graben in the resurgent dome. A potassium-argon age obtained from one of the north-trending rhyolite dikes is 14.7±0.4 Ma (Vander Meulen and others, 1987d). The northwest-trending rhyolite dike system intrudes the northwestern part of the Slocum Creek Wilderness Study Area and has a potassium-argon age of 14.9±0.4 Ma (Vander Meulen and others, 1987d). Several rhyolite domes and plugs of similar and younger age intrude the north and east margins of the caldera; this indicates an episode of ring-fracture volcanism. The rhyolite intrusions are locally brecciated, silicified, and cut by quartz veins.

Stratigraphy

The lowest stratigraphically exposed rocks in the study area are in the eastern uplifted part of the caldera. The rocks consist of an interbedded sequence of peralkaline rhyolite ash-flow tuff, air-fall tuff, and surge deposits that have a minimum thickness of 1,150 ft (Tlga and Tlgi, fig. 2). The interbedded tuffs and surge deposits were originally mapped as a single ash-flow tuff unit named the Leslie Gulch Ash-Flow Tuff Member of the Sucker Creek Formation by Kittleman and others (1965) (see also, Kittleman, 1973). On the basis of recent mapping, the Leslie Gulch Ash-Flow Tuff Member is here divided into three facies; they are an intracaldera facies consisting of ash-flow and air-fall tuff geographically restricted to the caldera, an outflow facies consisting of ash-flow tuff exposed outside the caldera (outside the area of figure 2), and an air-fall facies exposed within and adjacent to the caldera (Vander Meulen and others, 1987d). All three facies were deposited during the collapse of the Mahogany Mountain caldera. The intracaldera and air-fall facies are exposed over approximately two-thirds of the study area and underlie the entire study area at depth.

The intracaldera facies is best exposed in the central uplifted part of the caldera and covers approximately 0.8 mi^2 along the north-central part of the study area (fig. 2). It consists of ash-flow tuff and several interbedded air-fall and surge deposits that have a combined minimum thickness of 490 ft. Voluminous amounts of the intracaldera tuff probably filled the Mahogany Mountain caldera during its collapse, although the tuff units are presently exposed in only the deeply eroded resurgent dome. Estimated total original thickness of the intracaldera facies is 2,000 to 3,000 ft (Vander Meulen, 1988).

The intracaldera facies is a composite ash-flow tuff sheet comprised of several successive flow units that cooled as a single unit; the base of the tuff is not exposed. The intracaldera facies shows lateral and vertical variation through the section. The ash-flow tuff is generally poorly sorted, nonbedded, and contains discontinuous layers of pumice and lithic fragments; subtle eutaxitic foliation is common in the lower parts of the unit where heat and compression were greater. The composite ash-flow tuff contains several intervening air-fall tuffs and surge deposits composed of well-bedded ash and pumice lapilli. Beds of air-fall tuff are laterally continuous, whereas the surge deposits are laterally discontinuous. Both types of intervening deposits thicken toward a central-vent complex in the north-central part of the study area.

The air-fall facies is made up of bedded air-fall tuff and interbedded ash-flow tuff and surge deposits that have a combined minimum thickness of 650 ft. Outcrops of this unit are distributed over approximately two-thirds of the study area. Within the study area, the air-fall facies is separated from the underlying intracaldera facies by a gradational contact; rocks stratigraphically above the contact are dominantly air-fall tuffs and rocks below the contact are dominantly ash-flow tuffs. Angular, unflattened orangish-brown pumice fragments and light-green rhyolite lithic fragments are common throughout the air-fall facies. Pumice fragments are typically altered to clays and form pitted features in the tuff. Lithic fragments have vesicular rims that indicate they were molten when erupted. The pumice and juvenile lithic fragments are typically 0.5 to 1.3 in. in diameter. The upper part of the air-fall facies consists predominantly of water-laid, reworked light-brown to brownish-yellow ash. Blocks and bombs that are restricted to the lower part of the air-fall facies typically exceed 1 ft in length near the central-vent complex.

Near the north-central boundary of the study area, a 0.4- by 1-mi rhyolite vent complex (Trvi, fig. 2) intrudes and grades into the intracaldera tuffs (Vander Meulen, 1988). The tuffs and vent complex form part of the central resurgent dome of the Mahogany Mountain caldera. Radially outward dipping tuff beds surrounding the vent structure were tilted north during resurgent activity. The vent intrusions consist of matrix-supported autobreccia crosscut by dikes and plugs of flow-foliated rhyolite. Both sharp and gradational contacts exist between parts of the vent breccia and intracaldera tuff. The eastern margin of the vent generally forms a sharp contact with the intracaldera tuff. Along this margin, large chaotic blocks of intracaldera tuff as much as 35 ft across are contained in the vent breccia (Vander Meulen, 1988). Conversely, blocks of vent breccia as much as 4 ft in diameter are contained in the intracaldera tuff. Massive deposits of vent breccia merge with ash-flow tuff along the central and northern margins of the vent, whereas bedded deposits of breccia interfinger with air-fall tuff along the southern margin. Internal flow features are absent in the vent breccia. Geochemical correlations between the intracaldera tuff and vent intrusions, as well as facies changes in the tuff indicate that part of the intracaldera tuff erupted from the central vent (Vander Meulen, 1988). In the study area, parts of the vent complex and the adjoining tuffs are hydrothermally altered.

Following the collapse of the Mahogany Mountain caldera, two unrelated post-caldera rhyolite ash-flow tuffs erupted from nearby centers and ponded in the caldera depression. The tuff of Spring Creek (Tsc, fig. 2) first described by Vander Meulen and others (1987d) was the earliest ash-flow tuff to pond in the caldera and unconformably overlies the air-fall facies. The tuff of Spring Creek is a composite ash-flow tuff that erupted from the Three Fingers caldera (Vander Meulen and others, 1989) located 3 mi northeast of the Mahogany Mountain caldera. The tuff contains multiple ash-flow sheets, each less than 65 ft thick, that cooled as a single unit. Inside the caldera and near the central part of the study area, the tuff of Spring Creek has a minimum thickness of 1,000 ft where it fills the central graben. In the southwestern part of the study area near the topographic wall, the tuff of Spring Creek has a minimum thickness of 1,300 ft where it fills the southern part of the caldera depression (fig. 2).

The tuff of Birch Creek (Tbc, fig. 2) first described by Plumley (1986) is the younger of the two post-caldera ash-flow tuffs. The tuff probably vented from a source about 9 to 16 mi southwest of the Mahogany Mountain caldera. In the caldera, the thickness of this tuff ranges from 30 ft in the central part of the study area, where it conformably overlies the tuff of Spring Creek, to about 130 ft along the southwestern boundary of the study area, where it unconformably overlies the air-fall facies of the Leslie Gulch Ash-Flow Tuff Member. This post-caldera tuff thickens to an estimated 450 ft adjacent to the Owyhee River (fig. 1) 9 mi southwest of the study area. There, it forms an angular unconformity with the underlying outflow facies of the Leslie Gulch Ash-Flow Tuff Member.

Three rhyolite dike systems and several basalt dikes and plugs cut the entire sequence of intracaldera tuffs and are the youngest rocks in the study area. These rhyolite dikes (Trp, fig. 2) are highly resistant to erosion and form steep spired ridges that rise 2,000 to 3,000 ft above the intracaldera tuffs. Intracaldera tuffs adjacent to the rhyolite dikes are densely welded due to secondary heating. Secondary welding and silicification of the adjoining tuffs further contribute to the resistant nature of the rhyolite dikes. Hydrothermal alteration and silicification are common in parts of the dike systems and in the adjoining tuff. The rhyolite dikes are 1 to 16 ft wide and typically exhibit well-developed sets of horizontal columnar joints.

In the study area, alluvium is restricted to the main drainage canyons. The thickest areas of alluvium are probably along the northwestern part of the study area where they fill the lower part of Leslie Gulch.

Geochemical Studies

In 1987, the U.S. Geological Survey conducted a reconnaissance geochemical study of the Upper Leslie Gulch and Slocum Creek Wilderness Study Areas. Sixty-one rock samples, 30 stream-sediment samples, and 29 nonmagnetic heavy-mineral concentrates of stream sediments collected in and near the study area were analyzed during this study. Stream-sediment samples, and stream sediments from which the concentrates were derived, were collected from alluvium in active stream channels.

Stream sediments represent composites of rock and soil exposed upstream from sample sites. Stream-sediment samples are useful in identifying basins that contain concentrations of elements possibly related to mineralized rock. Nonmagnetic heavy-mineral concentrate samples provide information about the chemistry of a limited number of minerals in rock material eroded from the drainage basin upstream from each sample site. Many minerals found in the nonmagnetic fraction of heavy-mineral concentrates may be ore forming or ore related. Selective concentration of minerals permits determination of some elements that are not easily detected in bulk stream-sediment samples. Most rock samples appeared fresh and unaltered, and they were collected to determine geochemical background values. A few rock samples appeared altered and possibly mineralized; these were collected to determine the suite of elements associated with the observed alteration.

All samples were analyzed semiquantitatively for 31 elements (some for 35 elements) using the direct-current arc emission spectrographic method (Grimes and Marranzino, 1968). Stream-sediment and rock samples were also analyzed for certain elements of special interest or that have high lower limits of determination by the spectrographic method. Inductively coupled argon plasma-atomic emission spectroscopy (Crock and others, 1987) was used to analyze for antimony, arsenic, bismuth, cadmium, and zinc. Atomic absorption was used to analyze for gold (O'Leary and Meier, 1986) and for mercury (Crock and others, 1987). Uranium was determined by ultraviolet fluorescence using digestion method B described by O'Leary and Meier (1986). Analytical data are from M.S. Erickson (written commun., 1988).

Peralkaline rhyolite tuffs and intrusions associated with the Mahogany Mountain caldera have anomalously high thorium (18 parts per million, or ppm) and uranium (8 ppm) contents. Aerial gamma-ray surveys (Geometrics, Inc., 1979) that cover part of the caldera show uranium anomalies over the caldera. The anomalies probably reflect the high concentrations of thorium and uranium present in the intracaldera tuffs and intrusive rocks associated with the Mahogany Mountain caldera.

Caldera-forming tuffs adjacent to the central-vent complex in the northern part of the study area contain localized zones of hydrothermal alteration. Highly oxidized, altered zones exposed east of the vent complex generally follow stratified horizons in the bedded tuffs. Four rock samples collected from an altered zone in this area contain anomalous concentrations of thorium and uranium. The altered tuffs contain as much as 17 ppm thorium and 9 ppm uranium. Rock samples collected from the brecciated parts of the vent intrusion contain as much as 7 ppm uranium. Local high-grade vein-type uranium deposits are associated with peralkaline rhyolite intrusions in the McDermitt caldera complex (Rytuba and Glanzman, 1979). Similar deposits may be present at depth, adjacent to, or within the peralkaline rhyolite vent complex of the Mahogany Mountain caldera.

Two miles north of the study area, 4 rock samples collected from the outflow and air-fall facies of Leslie Gulch Ash-Flow Tuff Member contain anomalous values of lithium (170 to more than 200 ppm). Two samples of the tuff of Spring Creek collected stratigraphically above the outflow and air-fall facies also contain high values of lithium (more than 200 ppm). The peralkaline rhyolite tuffs associated with the Mahogany Mountain caldera are probably the source of high initial lithium concentrations. Samples from rhyolite dike systems in the central and northwestern parts of the study area contain 51 ppm and 81 ppm lithium, respectively. Remobilization and concentration of lithium in stratiform deposits may have occurred along the caldera margin during the last stages of caldera activity. In the study area, similar remobilization of the lithium may have occurred near or within the central-vent complex, along the rhyolite dike systems, or near any areas where residual heat may have initiated hydrothermal activity. Lithium deposits similar to those associated with peralkaline rhyolites of the McDermitt caldera (Rytuba, 1981) may be present at depth in the Mahogany Mountain caldera.

Peralkaline rhyolite tuffs and intrusions associated with the Mahogany Mountain caldera have exceptionally high zinc concentrations that are probably attributable to chlorine enrichment of the magma (Rytuba, 1981). Forty-four rock samples of caldera-forming ash-flow and air-fall tuff and 11 samples of vent breccia were analyzed for zinc by X-ray-fluorescence spectroscopy. Thirty-three of these samples were collected in the study area; zinc values of these samples typically range from 180 to 250 ppm and some values are as high as 688 ppm.

Several high-silica rhyolite plugs and dikes that are locally cut by quartz veins occur in the central and northwestern parts of the study area. Samples of fractured rhyolite and quartz veins collected 2 mi north of the study area contain anomalous concentrations of arsenic (30 ppm), mercury (2.8 ppm), and zinc (250 ppm). The high zinc content probably reflects normal magmatic enrichment and (or) concentrations derived from hydrothermal systems active during the close of the caldera cycle. No gold was detected in these samples.

Two heavy-mineral concentrate samples that were collected from the northwestern part of the Slocum Creek Wilderness Study Area contain 3,000 and 200 ppm lead. Both samples are probably contaminated, possibly from oxidized lead particles eroded from artifacts such as bullets.

Anomalous concentrations of barium were detected in three heavy-mineral-concentrate samples and one rock sample collected from widely spaced sites in the Slocum Creek Wilderness Study Area. The anomalous barium concentrations ranging from 5,000 ppm to more than 10,000 ppm are due to the occurrence of barite in the samples as detected by microscopic examination.

An anomalous concentration of tin (more than 2,000 ppm) was detected in a heavy-mineral-concentrate sample collected from a tributary of Slocum Creek in the northern part of the Slocum Creek Wilderness Study Area. The sample contains a few grains of cassiterite, of the variety known as wood tin. On the basis of the extremely small amount of cassiterite in the sample, we do not believe a significant amount of tin is present in the study area.

Geophysical Studies

Geophysical evaluation of the mineral resources of the Upper Leslie Gulch and Slocum Creek Wilderness Study Areas is based on interpretations of radiometric, aeromagnetic, and gravity surveys.

An aeromagnetic survey that includes both study areas was conducted in 1976 and 1977 by Oregon State University during a study of the Vale-Owyhee geothermal area (Boler, 1979). The aeromagnetic data were collected along parallel east-west flightlines spaced 1 mi apart and flown at a constant barometric elevation of 7,000 ft above sea level. The Earth's main magnetic field was subtracted from the data that were plotted by machine and hand-contoured at a scale of 1:62,500. The final residual map was drafted at a scale of 1:125,000.

Additional aeromagnetic data are available in the atlas on the Boise 1° by 2° quadrangle published for the U.S. Department of Energy NURE program (Geometrics, Inc., 1979). The data were taken along east-west flightlines spaced at intervals of 3 mi flown by helicopter at an average height of 400 ft above the ground. Two profiles compiled from the data cross the wilderness study area.

Variations in the Earth's magnetic field on an aeromagnetic residual map are, in general, related to the amount of magnetic minerals in the rocks. Magnetite is the common magnetic mineral in the rocks underlying this region. Magnetic minerals, where locally concentrated or absent, may cause a high or low magnetic anomaly that can be a guide to mineral occurrences or deposits. At these magnetic latitudes, the inclination of the Earth's main magnetic field is relatively steep (68° below horizontal); therefore, boundaries between magnetic and relatively less magnetic rock are located approximately at the steepest gradient along the flanks of a magnetic anomaly.

The survey aircraft collecting aeromagnetic data for the Boler (1979) study was generally more than 2,000 ft above the ground, a distance sufficient to suppress most short wavelength anomalies generated by rocks at or near the surface. The contour magnetic map (Boler, 1979) shows a 3- to 4-mi-wide linear magnetic low trending approximately N. 35° E. across the center of the study area. The low is probably associated with thick sections of weakly magnetic ash-flow tuff that fill the Mahogany Mountain caldera. Magnetic highs bound the magnetic low on the southeast and northwest sides. The crests of the

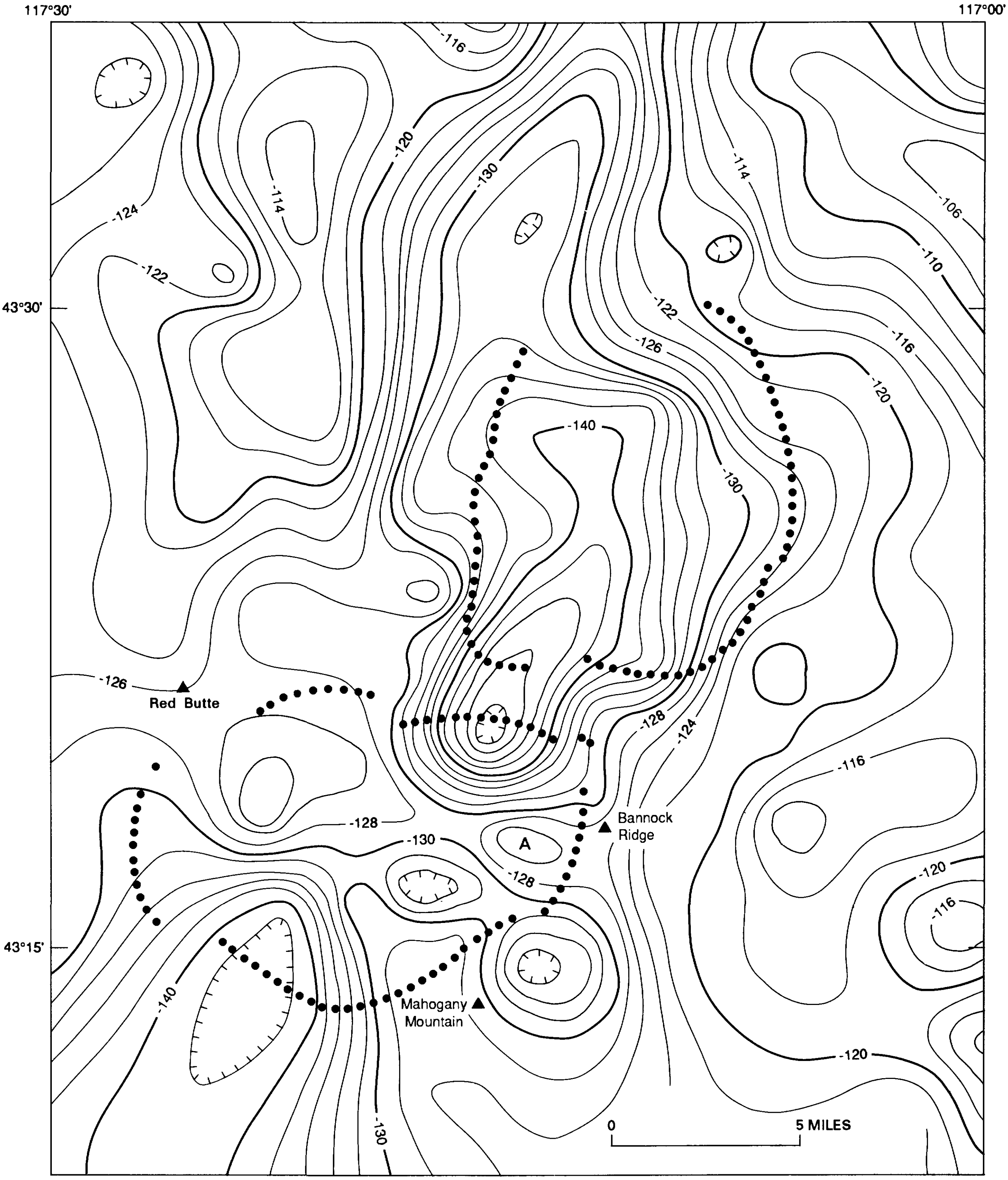


Figure 3. Bouguer gravity anomaly map of Owyhee volcanic field, eastern Oregon. Heavy dotted lines, approximate margins of Mahogany Mountain caldera (south) and Three Fingers Caldera (north). Contour interval, 2 milligal; hachured in direction of gravity low. See text for discussion of anomaly A.

highs are located beyond the borders of the study area. The southeastern magnetic high appears to be caused by a substantial thickness of older precaldera rhyolites (Vander Meulen and others, 1987d) that make up Mahogany Mountain. The northwestern magnetic high has a substantial width (10 mi) and represents a causative rock mass at least 5,000 ft thick. The rock mass is concealed by relatively nonmagnetic clastic rocks of the Sucker Creek Formation and the Deer Butte Formations of Kittleman and others (1967). These data indicate normal magnetic features for this complex volcanic area and do not appear to have any economic significance.

Gravity data for the region are available from the National Geophysical Data Center (1984). Most data were gathered from an earlier survey conducted by students of Oregon State University. The earlier survey was described and generally interpreted in a thesis by Lillie (1977). Additional gravity stations were located within and near the study area by Plouff (1987). Average spacing between stations within and near the study area is 2 to 3 mi. Complete Bouguer gravity data were contoured at an interval of 2 mGal (milligals) and a reduction density of 2.67 grams per cubic centimeter or g/cm^3 (fig. 3).

Several coalescing gravity lows are associated with rocks in the study area. These lows and a major gravity low extending 15 mi north (fig. 3) have been interpreted by Plouff (Rytuba and others, 1985; Vander Meulen and others, 1987c) as the expression of thick low-density ash-flow tuff, air-fall tuff, and sedimentary rock filling a caldera. Within the study area, three coalescing gravity lows are associated specifically with the Mahogany Mountain caldera. The coalescing lows of about 10 mGal partly coincide with the caldera. The southern edge of the gravity anomaly generally follows the topographic wall of the caldera along Mahogany Mountain but locally extends as much as 3 mi beyond the caldera margin to the southeast. The western part of the caldera has no clearly identifiable expression on the gravity map. The northern extension of the gravity low probably reflects a subsided wedge of tuffaceous sedimentary rock, and a substantial thickness of ash-flow and air-fall tuff that fill the Three Fingers caldera and Honeycombs volcanic center (Vander Meulen and others, 1987b)

The northern elongated gravity low that includes the Mahogany Mountain caldera, Three Fingers caldera, and Honeycombs volcanic center indicates a caldera complex about 25 mi long and 10 mi wide. The small closed gravity contour that expresses a high near the center of the eastern part of the Mahogany Mountain caldera (A, fig. 3) is probably associated with the resurgent dome. Either an uplifted central floor or a central intrusion within the resurgent dome may have caused local thinning of low-density intracaldera tuffs. A linear gravity gradient trending north-south along the west side of the caldera complex is part of a longer feature extending on strike at least 25 mi farther north. The linear feature is probably the gravity expression of a major north-trending fault zone near the western border of the Slocum Creek Wilderness Study Area.

Aerial gamma-ray-spectrometer measurements for uranium, thorium, and potassium taken along 3-mi-spaced flightlines are available in Geometrics, Inc. (1979). Statistically significant uranium anomalies were detected over the Upper Leslie Gulch Wilderness Study Area. The anomalies are 2 to 3 standard deviations above the average values for the Boise 1° by 2° quadrangle. Anomalies near the southern margin of the Mahogany Mountain caldera and over the central part of the caldera correlate with a region of high potassium values. Conversely, the gravity low extending north to the Honeycombs volcanic center does not correlate with particularly high potassium concentrations. Peralkaline rhyolite tuffs and intrusions of the Mahogany Mountain caldera are probably the source for the high potassium and uranium concentrations. However, the potassium anomalies may be in part related to the introduction of potassium by hydrothermal alteration.

Mineral and Energy Resource Potential of the Upper Leslie Gulch Wilderness Study Area

Parts of the study area underlain by caldera-forming ash-flow and air-fall tuffs have moderate potential for uranium and thorium resources, level C certainty. Except for a few isolated outcrops of post-caldera tuff, the caldera-forming tuffs underlie the entire study area (fig. 2). The mineral resource potential rating is based on anomalous concentrations of uranium and thorium detected in rock samples and on anomalous aerial gamma-ray values for these elements over the study area.

Peralkaline rhyolite tuff and intrusions associated with the Mahogany Mountain caldera have high concentrations of lithium, as do samples collected from the overlying post-caldera tuffs, though not as high as the peralkaline tuff and intrusions. Stratiform lithium deposits similar to those associated with peralkaline rhyolite of the McDermitt caldera (Rytuba, 1981) may be present in the study area. All tuffs in the study area have low potential for lithium resources in stratiform deposits, level C certainty.

Samples of caldera-forming tuffs have extraordinarily high zinc concentrations. The high zinc concentrations are associated with pumice fragments in these rocks. Volcanogenic disseminated zinc deposits of this type were previously unrecognized in the world. Areas underlain by the tuffs are assigned low potential for zinc resources, level B certainty.

An exploration company—Manville International Group—is currently prospecting for gold (Au) deposits northeast of the study area. The Bannock gold prospect, 2 mi northeast of the study area (fig. 1), is associated with a rhyolite ring-dome complex that intrudes the eastern margin of the Mahogany Mountain caldera. The Katie gold prospect, 7 mi northeast of the study area (fig. 1), is associated with rhyolite ring-domes and northwest-striking fault zones that cut the east margin of the Three Fingers caldera. Best assays of as much as 0.5 troy oz Au/short ton and 6 troy oz Ag (silver)/short ton, accompanied by high selenium content, occur in a rhyolite dome. Mineralized zones consist of hairline fractures filled with quartz and black sulfide minerals. Rhyolite dikes and plugs exposed 3 mi northwest of the study area, near the north margin of the Mahogany Mountain caldera, are locally brecciated and cut by quartz veins. There, the rhyolites contain anomalous concentrations of arsenic, mercury (pathfinder elements for gold and silver deposits), and zinc (Vander Meulen and others, 1987c). Hydrothermal activity during the close of the caldera cycle probably concentrated these elements. Similar rhyolite dike systems extend south across the western part of the study area. Because of the mineral association in the Mahogany Mountain caldera, all rhyolite intrusions in the study area have moderate potential for gold, silver, mercury, and zinc resources, level B certainty.

An unnamed hot spring issues from a north-trending, high-angle normal fault about 6 mi west of the study area (fig. 1). Recorded temperature of the spring water is 50 °C (Bliss, 1983). Several thermal springs and wells are located about 17 mi north of the study area (Oregon Department of Geology and Mineral Industries, 1982). One area, less than 11 mi north of the study area, may be underlain at shallow depth (less than 3,280 ft) by thermal water of sufficient temperature for direct heat applications (Oregon Department of Geology and Mineral Industries, 1982). No hot springs or recent fault zones were mapped in the study area, although both are present in the adjoining study area. The Upper Leslie Gulch Wilderness Study Area has unknown potential for geothermal resources, certainty level A.

The Upper Leslie Gulch Wilderness Study Area is located within the Mahogany Mountain caldera. Post-caldera sedimentary rocks that commonly accumulate in caldera depressions may contain oil and gas resources. The study area is located over the eastern part of the caldera's central resurgent dome, an area that has been uplifted and deeply eroded. No post-caldera sedimentary rocks are preserved in the study area. Any petroleum or natural gas reservoirs trapped in precaldera sedimentary rocks would have been destroyed by magmatic heat accompanying caldera formation. Therefore, the study area has no potential for oil and gas resources, level D certainty.

Mineral and Energy Resource Potential of the Slocum Creek Wilderness Study Area

Samples collected from caldera-forming ash-flow and air-fall tuff in the Slocum Creek Wilderness Study Area contain anomalous concentrations of uranium and thorium. The caldera-forming tuff probably underlies the entire study area but is buried by thick deposits of post-caldera tuff in the northwestern and southeastern parts of the study area (fig. 2). Samples collected from a rhyolite vent complex associated with the caldera also contain anomalous concentrations of uranium and thorium. The vent complex intrudes the central part of the caldera along the northeastern boundary of the study area. On the basis of anomalous thorium and uranium values detected in an aerial gamma-ray survey flown over the caldera, parts of the study area underlain by caldera-forming ash-flow and air-fall tuff and the vent complex (fig. 2) have moderate potential for uranium and thorium mineral resources, level C certainty. These elements were probably concentrated by hydrothermal activity during the last stages of caldera formation.

Peralkaline rhyolite tuff and intrusions associated with the Mahogany Mountain caldera have high concentrations of lithium, as do samples collected from the overlying post-caldera tuffs, though not as high as the peralkaline tuff and intrusions. Stratiform lithium deposits similar to those associated with peralkaline rhyolite of the McDermitt caldera (Rytuba, 1981) may be present in the study area. All tuffs in the study area have low potential for lithium resources in stratiform deposits, level C certainty.

Samples of caldera-forming tuffs and vent breccia intrusions contain extraordinarily high zinc concentrations. The high zinc concentrations are associated with pumice fragments in these rocks. Volcanogenic disseminated zinc resources of this type were previously unrecognized in the world. Areas underlain by the tuffs and vent breccia are assigned low potential for zinc resources, level B certainty.

An exploration company—Manville International Group—is currently prospecting for gold deposits northeast of the study area. The Bannock gold prospect, 5 mi northeast of the study area (fig. 1), is associated with a rhyolite ring-dome complex that intrudes the eastern margin of the Mahogany Mountain caldera. The Katie gold prospect, 9 mi northeast of the study area (fig. 1), is associated with rhyolite ring-domes and northwest-striking fault zones that cut the east margin of the Three Fingers caldera. Best assays of as much as 0.5 troy oz Au/short ton and 6 troy oz Ag/short ton, accompanied by high selenium content, occur in a rhyolite dome. Mineralized zones consist of hairline fractures filled with quartz and black sulfide minerals. Rhyolite dikes and plugs exposed 1.5 mi north of the study area, near the northern margin of the Mahogany Mountain caldera, are locally brecciated and cut by quartz veins. The rhyolites contain anomalous concentrations of arsenic, mercury (pathfinder elements for gold and silver deposits), and zinc (Vander Meulen and others, 1987c). Hydrothermal systems active during the close of the caldera cycle likely concentrated these elements. Similar rhyolite dike systems extend south across the eastern and northwestern parts of study area. Because of the mineral association in the Mahogany Mountain caldera, all rhyolite intrusions in the study area have moderate potential for gold, silver, mercury, and zinc resources, level B certainty.

An unnamed hot spring that issues from a north-trending normal fault 2 mi west of the study area (fig. 1) has a recorded temperature of 50 °C (Bliss, 1983). Several thermal springs and wells are located about 16 mi north of the study area (Oregon Department of Geology and Mineral Industries, 1982). One area, less than 10 mi north of the study area, may be underlain at shallow depth (less than 3,280 ft) by thermal water of sufficient temperature for direct heat applications (Oregon Department of Geology and Mineral Industries, 1982). Although no hot springs were identified in the study area, geothermal waters may exist at depth along recent fault zones in and adjacent to the western part of the study area. Areas adjacent to these fault zones have moderate potential for geothermal resources, level C certainty.

The Slocum Creek Wilderness Study Area is located within the Mahogany Mountain caldera. Post-caldera sedimentary rocks that commonly accumulate in caldera depressions may contain oil and gas resources. The study area is located over the eastern part of the caldera's central resurgent dome, an area that has been uplifted and deeply eroded. No post-caldera sedimentary rocks are preserved in the study area. Any petroleum or natural gas reservoirs trapped in precaldera sedimentary rocks would have been destroyed by magmatic heat accompanying caldera formation. The study area has no potential for oil and gas resources, level D certainty.

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

LEVEL OF CERTAINTY →

Abstracted with minor modifications from:

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