Mineral Resources of the Upper West Little Owyhee Wilderness Study Area, Malheur County, Oregon

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Chapter H

Mineral Resources of the Upper West Little Owyhee Wilderness Study Area, Malheur County, Oregon

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U.S. GEOLOGICAL SURVEY BULLETIN 1719

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
OWYHEE RIVER REGION, IDAHO AND NEVADA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1988

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Federal Center, Box 25425
Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

Mineral resources of the Upper West Little Owyhee
Wilderness Study Area, Malheur County, Oregon

(U.S. Geological Survey Bulletin ; 1719-H)
Bibliography: p.
Supt. of Docs. no. : I 19.3:1719-H
1. Mines and mineral resources—Oregon—Upper West
Little Owyhee Wilderness. 2. Upper West Little Owyhee
Wilderness (Or.) I. Evans, James George, 1938-
II. Series
QE75.B9 no. 1719-H 557.3 s 88-600061
[TN24.07] [553'.095'97]

STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Area

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Upper West Little Owyhee Wilderness Study Area (OR-003-173), Malheur County, Oregon.

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MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
OWYHEE RIVER REGION, IDAHO AND NEVADA

Mineral Resources of the Upper West Little Owyhee Wilderness Study Area, Malheur County, Oregon

By James G. Evans, Robert L. Turner, Donald Plouff, *and* Don L. Sawatzky
U.S. Geological Survey

J. Mitchell Linne
U.S. Bureau of Mines

SUMMARY

Abstract

At the request of the Bureau of Land Management, the Upper West Little Owyhee Wilderness Study Area and adjacent areas, totaling approximately 62,500 acres, were evaluated for mineral resources and mineral resource potential. Throughout this report, "wilderness study area" and "study area" refer to the 62,500 acres for which mineral surveys were requested. The U.S. Geological Survey and the U.S. Bureau of Mines conducted geological, geophysical, and geochemical surveys to assess the identified mineral resources (known) and mineral resource potential (undiscovered) of the study area. Field work for this report was carried out in 1984 and 1985. No mines, significant prospects, or mining claims are located inside the study area, and no mineral resources were identified. The western part of the study area has low potential for mercury and the central part has low potential for mercury and silver. The entire study area has low potential for oil and gas. The study area has no potential for geothermal resources.

Character and Setting

The Upper West Little Owyhee Wilderness Study Area is located on the Owyhee Plateau, 12 mi northeast of McDermitt, Nevada (fig. 1). The area has a total relief of 1,450 ft and consists of broad flat areas and rolling hills cut by canyons incised to depths of 400 ft. The area is underlain by flat-lying volcanic, pyroclastic, and sedimentary rocks of middle Miocene through Holocene age (fig. 2) (see appendixes for geologic time chart). The Swisher Mountain Tuff is the oldest and most abundant rock unit in the study area. Basalt overlies the Swisher Mountain Tuff and forms low, rounded buttes that are probably remnants of shield volcanoes. One steep, arcuate fault offsets basalt against Swisher Mountain Tuff in the northern part of the study area.

Identified Mineral Resources

No identified mineral resources were classified in the study area. Although zeolite of the heulandite group was found in a tuff bed, the volume of the tuff is too small for the occurrence to constitute an identified resource.

Mineral Resource Potential

The western part of the Upper West Little Owyhee Wilderness Study Area has low mineral resource potential for mercury (fig. 2). The central part of the study area has a low potential for silver and mercury resources. These metals are associated with zones of possible weak epithermal alteration on the west flank of the Horse Hill basalt vent and the east flank of the Summit 6518 basalt vent. The entire study area has low potential for oil and gas resources. The study area has no potential for geothermal resources.

INTRODUCTION

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

Publication authorized by the Director, U.S. Geological Survey, March 15, 1988.

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

Area Description

The Upper West Little Owyhee Wilderness Study Area (OR–003–173) covers approximately 62,500 acres along the West Little Owyhee River and Big Antelope Creek and adjacent parts of the Owyhee Plateau northeast of McDermitt, Nev. (fig. 1). Terrain in the study area is generally flat to gently rolling, rising gradually from approximately 5,600 ft in the north to more than 6,400 ft in the southwest corner and at Horse Hill, near the center of the study area. Canyons cut by

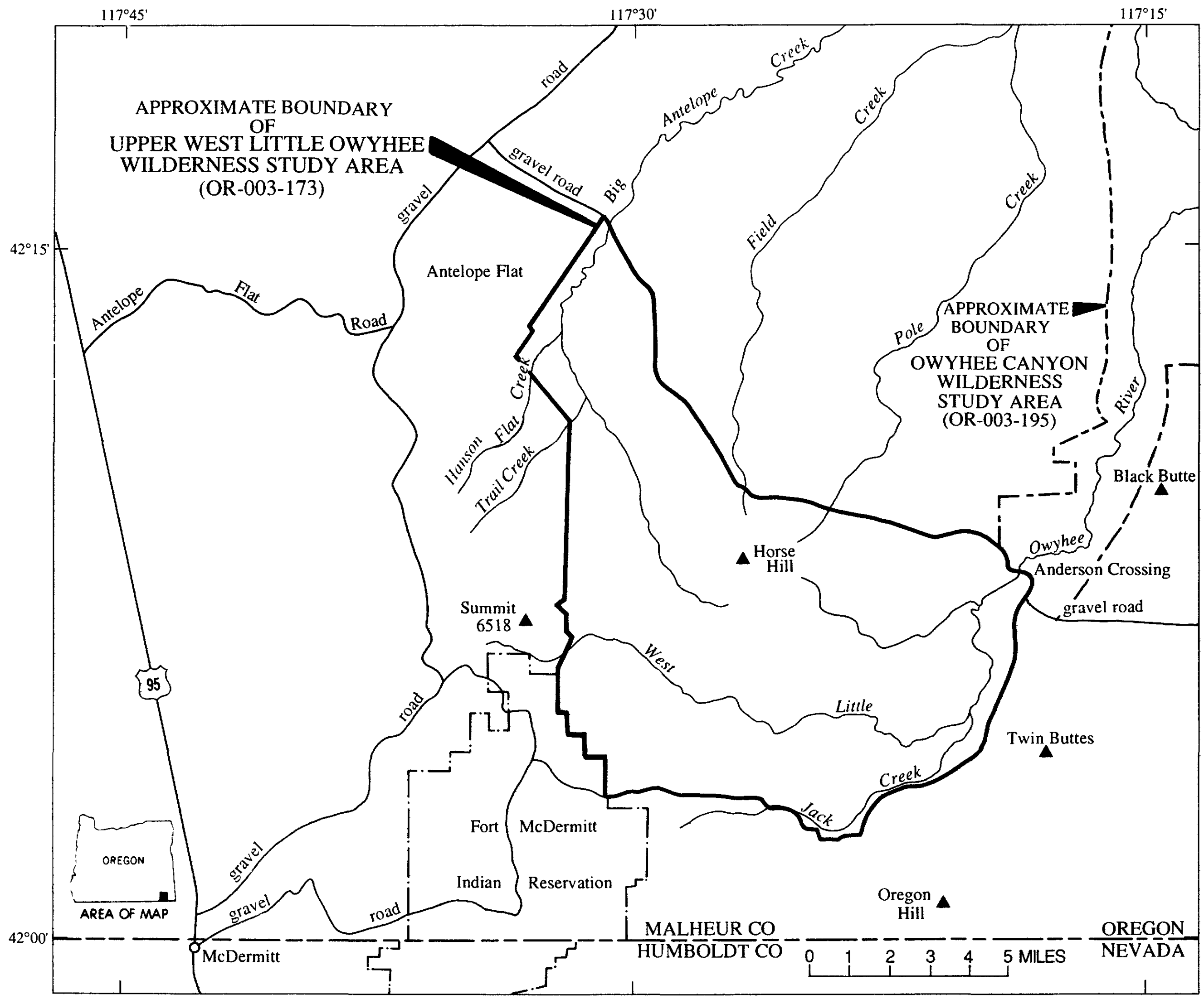

Figure 1. Index map showing location of Upper West Little Owyhee Wilderness Study Area, Malheur County, Oregon.

the West Little Owyhee River and Big Antelope Creek are as much as 400 ft deep. The arid climate supports sagebrush, rabbit brush, and sparse native grasses. Stands of cottonwood, aspen, and willow occur below the canyon rims. The area is used for cattle grazing and also supports mule deer, pronghorn antelope, and numerous species of birds, small mammals, and reptiles.

The study area is most easily accessible from Antelope Flat Road, which joins U.S. Highway 95 15 mi north of McDermitt, Nev. (fig. 1). A branch of this road forms the north boundary of the study area and crosses the West Little Owyhee River at Anderson Crossing. Several jeep trails branch from this road to provide access to points in the study area. The southwestern part of the study area can also be reached by very rough jeep trails from McDermitt through the Fort McDermitt Indian Reservation.

Previous and Present Investigations

Reconnaissance geologic maps that include the study area were published by Walker and Repenning (1966) and by Walker (1977). Hart (1982), Hart and Aronson (1983), Hart and Mertzman (1983), Gray and others (1983), and Hart and others (1984) studied the stratigraphy and chemistry of volcanic rocks in southeastern Oregon and adjacent regions, including the Upper West Little Owyhee Wilderness Study Area.

The U.S. Geological Survey carried out field investigations in the study area during 1985. This work included geologic mapping at the scale of 1:24,000 and geochemical sampling. Rock samples were collected for petrographic analysis. Geochemical data were obtained from 66 stream sediment samples, 66 heavy-mineral concentrate samples, and 11 rock samples (R.L. Turner, unpub. data, 1987).

The U.S. Bureau of Mines examined Malheur County records and Bureau of Land Management master title plats and records for mining claims in the study area. Additional information was obtained from U.S. Bureau of Mines' library materials and production records. A field search was conducted in July 1986 for prospects or mineralized zones in or near the study area. Three alluvial samples, 7 rock samples, and 7 stream-sediment samples were collected and analyzed. The alluvial samples were scanned for heavy minerals. Six of the rock samples were analyzed for gold and silver by fire assay-atomic absorption spectroscopy, and 5 were analyzed for 23 elements by inductively coupled plasma spectroscopy (ICP). One rock sample was analyzed for 26 elements by neutron activation. One rock sample was analyzed for zeolites by X-ray diffraction. Stream-sediment samples were analyzed for 30 elements by ICP and for gold by fire assay-atomic absorption spectroscopy. All samples were checked for radioactivity and fluorescence. Sample analyses are on file at the U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Ave., Spokane, WA 99202.

APPRAISAL OF MINERAL RESOURCES

By J. Mitchell Linne
U.S. Bureau of Mines

Mining History

No history of mining or prospecting is known within or near the study area. The closest mining activity is at the McDermitt caldera complex, 25 mi southwest of the study area.

Mineral Resources

No metallic mineral resources were identified in the study area. One stream-sediment sample and four basalt samples contained 0.2 ppm (parts per million) silver. No other geochemical anomalies were found. One sample of air-fall tuff contained 50 to 75 percent zeolite of the heulandite group. This sample was from a thin tuff layer exposed between basalt flows near the north boundary of the study area. Due to its small volume it is not classified as a mineral resource (Linne, 1987). Basalt can be used for several commercial purposes, but it is not considered to have resource potential in the study area because it is common throughout the region and other sources occur closer to the sites of probable use.

In its draft Environmental Impact Statement on Oregon Wilderness, the U.S. Bureau of Land Management (1985) identified an area with medium potential (very low confidence level) for manganese on the south flank of Horse Hill. Because the area was designated as having potential, stream-sediment and rock samples from the area were collected and analyzed. No samples contained more than 1,500 ppm manganese, a concentration that is typical for basalt and does not indicate significant mineralization.

Sand and gravel deposits in the West Little Owyhee River, Jack Creek and Big Antelope Creek are not considered a resource because larger sand and gravel deposits in the region are more accessible.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By James G. Evans, Robert L. Turner, Donald Plouff, *and* Don L. Sawatzky
U.S. Geological Survey

Geology

The Upper West Little Owyhee Wilderness Study Area is underlain chiefly by flat-lying Tertiary welded rhyolite tuff and basalt flows (fig. 2). The oldest rock unit in the study area is the Swisher Mountain Tuff (Ekren and others, 1984). In the study area, the Swisher Mountain Tuff is composed of black to dark-gray and purple, massive to laminated, vitrophyre breccia containing fragments as much as 1 ft across, and devitrified welded tuff. These rocks are continuous with the welded ash-flow tuff unit described by Evans and others (1987) in the Owyhee Canyon Wilderness Study Area just north of Anderson Crossing (fig. 1) that is also considered to be Swisher Mountain Tuff. In the study area, the Swisher Mountain Tuff contains as much as 55 percent angular to rounded phenocrysts and lithic fragments. Lithic fragments include vitrophyre, vitrophyre breccia, laminated welded tuff, and metabasalt and are as much as 0.3 in. across. Phenocrysts

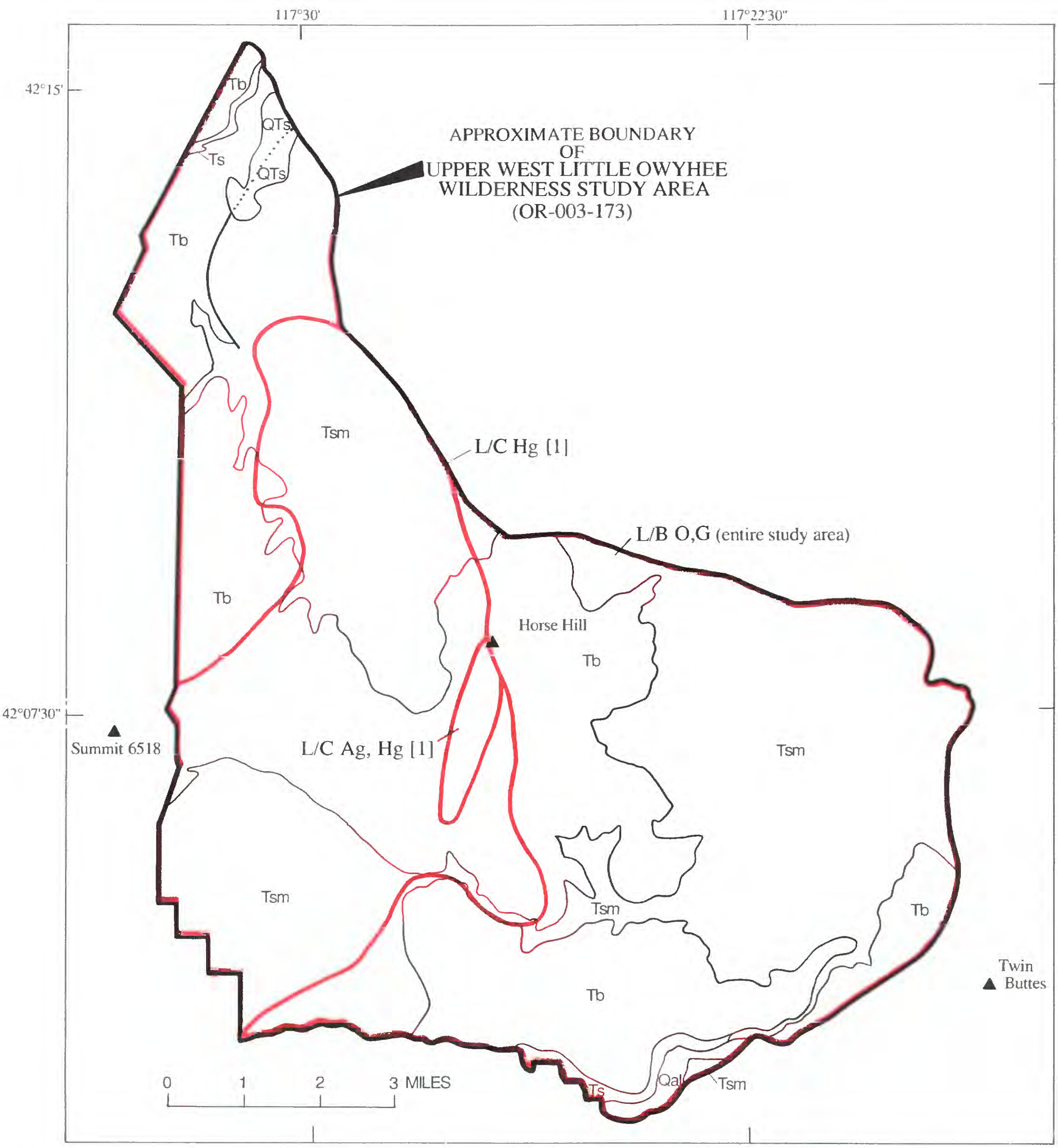

Figure 2. Mineral resource potential and generalized geology of the Upper West Little Owyhee Wilderness Study Area, Malheur County, Oregon.

consist mostly of plagioclase (andesine), but also include lesser amounts of quartz, potassium feldspar (sanidine, perthite), clinopyroxene and orthopyroxene, magnetite, hematite, hornblende, and olivine that is partly altered to bowlingite. Phenocrysts and lithic fragments show features related to strain, including fractures, brecciation, and, in quartz phenocrysts, extinction shadows and deformation lamellae. Magnetite and hematite are minor constituents; the hematite is locally disseminated along lamellae and forms rims on magnetite and pyroxene grains. Devitrification has resulted in crystallization of quartz and feldspar in the matrix; microspherulites and perlitic cracks are abundant. Zeolites, chalcedony, epidote, chlorite, and carbonate are present in some of the rocks.

Minimum thickness of the Swisher Mountain Tuff in the study area is estimated at 400 ft; the maximum thickness is exposed in canyon walls along the Upper West Little Owyhee River. However, the base is not exposed and approximately 1,000 ft of the formation is exposed north of the study area in the Owyhee Canyon Wilderness Study Area (Evans and others, 1987). Geophysical evidence in the region suggests that the Swisher Mountain Tuff was deposited as a result of caldera-forming eruptions in southwest Idaho.

Potassium-argon ages on samples of the Swisher Mountain Tuff are Middle Miocene, ranging from 12.5 to 14.6 Ma (million years before present) (Hart and Aronson, 1983; Neill, 1975). A sample of the vitrophyre at Anderson Crossing gives a potassium-argon age of 13.58 ± 0.63 (whole rock) and 13.07 ± 0.59 Ma (glass) (Hart and Aronson, 1983).

EXPLANATION

Area of low mineral resource potential--See appendix for definition of levels of mineral resource potential (L) and certainty of assessment (B,C)

Commodities

Ag	Silver
Hg	Mercury
O,G	Oil and gas
[1]	Epithermal alteration

Geologic map units

Qal	Alluvium (Quaternary)
QTs	Tuffaceous sandstone (Quaternary or Tertiary)
Ts	Siltstone (Pliocene or Miocene)
Tb	Basalt (Pliocene or Miocene)
Tsm	Swisher Mountain Tuff (middle Miocene)

Contact

Fault--Dotted where concealed

Figure 2. Continued.

Black to dark-gray basalt flows, showing crude columnar joints and platy fractures, unconformably overlie the Swisher Mountain Tuff. These flows are as much as 100 ft thick near Horse Hill and Summit 6518, west of the study area. Basalt flows in the study area are also described by Walker and Repenning (1966), Hart (1982), Hart and Mertzman (1982, 1983), and Hart and others (1984). In the study area the basalt flows are generally massive, but locally exhibit flow breccia-tion and flow layering defined by arrays of phenocrysts. The flows are commonly diktytaxitic and contain as much as 15 percent vesicles as much as 0.8 in. across that are partly to completely filled with white zeolites and calcite. The rock is aphyric to porphyritic with as much as 20 percent phenocrysts of plagioclase and olivine as much as 0.15 in. long. Some of the rock is glomeroporphyritic with clumps of plagioclase and olivine 0.4 in. across. Major constituents are plagioclase (labradorite, 40–55 percent), olivine (1–25 percent), and clinopyroxene (20–40 percent). Clinopyroxene is commonly ophitic. Ilmenite, magnetite, and hematite are minor constituents. Olivine is slightly altered to bowlingite and iddingsite along grain margins.

Regionally, basalt was extruded during three main pulses: 7 to 10 Ma, 3.5 to 6 Ma, and 0 to 2.5 Ma (Hart, 1982; Hart and others, 1984). However, it is not clear which of the pulses created the Horse Hill and Summit 6518 basalt flows. North of the study area, basalt flows in the Owyhee Canyon Wilderness Study Area give ages ranging from 11.5 to 1.5 Ma (Hart, 1982; Hart and Mertzman, 1983). A basalt flow at Anderson Crossing that was extruded from Black Butte, 4 mi northeast of the study area, was dated at 5.04 ± 0.81 Ma (Hart, 1982). The lack of well-preserved volcanic landforms in the study area suggests that the basalt flows are Pliocene or older. In this report the basalt of the study area is tentatively assigned a Miocene and (or) Pliocene age.

Light-brown, moderately well-lithified, conglomeratic siltstone, 50 ft thick or less, is interbedded with basalt at the north end of the study area. Siltstone, as thick as 100 ft, underlies the basalt at the south end of the study area. The siltstone contains 50 percent small (less than 0.12 in. diameter), angular to rounded clasts of massive and laminated densely welded tuff, basalt, metachert, and vitrophyre. Grains, as much as 0.02 in. long, include tourmaline, magnetite that is partly altered to hematite, plagioclase, biotite that is partly altered to chlorite, clinopyroxene, and hornblende. Clear and brown glass shards are common.

A well-cemented conglomeratic tuffaceous sandstone is deposited over a fault that offsets basalt against Swisher Mountain Tuff at the north end of the study area. The sandstone contains conspicuous angular black basalt pebbles as much as 0.4 in. across in a matrix of sand, silt, and clay with silica cement. The matrix contains small clasts of basalt, siltstone containing diatom frustules, perlitic brown glass, clear glass shards, and devitrified welded tuff that are no more than 0.04 in. across. Some of the welded tuff clasts are altered to zeolites on the margins. Grain fragments include quartz, olivine that is partly altered to bowlingite, plagioclase, zeolites, pyroxene, and hornblende. Total pyroclastic fraction of the sandstone is 45 percent. Age of the tuffaceous sandstone is clearly younger than the basalt and is therefore between late Miocene and Quaternary.

The metachert clasts in the siltstone suggest that, between episodes of basalt volcanism in the study area, the area was connected by through-going drainages to sources of metasedimentary rock outside of the Owyhee Plateau. Chert and quartzite clasts are common in stream gravels in the Owyhee River 22 mi northeast of the study area; sources of these clasts are most likely upstream in Idaho and Nevada. These sources may also have supplied sediments to the ancestral Owyhee River drainage during Miocene and (or) Pliocene time.

Holocene deposits include alluvium along parts of Big Antelope Creek, Jack Creek, and West Little Owyhee River and playa deposits on the basalt flows around Horse Hill.

An arcuate fault separates basalt flows and the Swisher Mountain Tuff at the north end of the study area. Stratigraphic separation could be as much as 140 ft at the north end of the fault, but probably is less than that because the base of the basalt flows slopes up eastward toward the Swisher Mountain Tuff. Walker and Repenning (1966) mapped several steep northeast-striking faults and one northwest-striking fault in the western part of the study area. These faults were not found by Evans (unpub. data, 1985).

Geochemical Studies

A reconnaissance geochemical survey was conducted in the Upper West Little Owyhee River Wilderness Study Area in the summer of 1986. Minus-80-mesh stream-sediment samples, nonmagnetic heavy-mineral concentrates derived from stream sediments, and rocks were selected as the sample media in this study. Samples of stream sediments and heavy-mineral concentrates were collected at 66 sites and 11 rock samples were collected at additional sites.

Stream-sediment samples were collected from active alluvium in stream channels. Each sample was collected from several localities along a channel length of approximately 50 ft. Stream sediments represent a composite sample of the rock and soil exposed upstream from the sample site. The heavy-mineral concentrate represents a concentration of any ore-forming and ore-related minerals present that permits determination of some elements that are not easily detected in bulk stream sediments.

Rocks were taken from mineralized and unmineralized outcrop and stream float. Samples that appeared fresh and unaltered were collected to provide information on geochemical background values. Altered or mineralized samples were collected to determine the suite of elements associated with the observed alteration or mineralization.

The heavy-mineral concentrates, stream sediments, and rocks were analyzed for 31 elements by direct-current arc, semiquantitative, emission spectrographic analysis (Grimes and Marranzino, 1968). Other elements were analyzed by atomic-absorption methods (antimony, arsenic, bismuth, cadmium, zinc) by the method described by O'Leary and Viets (1986), gold by the method described by Thompson and others (1968), and mercury by the method described by Koirtyohann and Khalil (1976). These analyses were used to identify drainages with anomalous concentrations of minor elements. Anomalous concentrations in stream sediment and rock samples were determined by comparing the analytical data with the average abundance for rock types in the drainages. Abundance data are from Rose and others (1979). Concentrations of at least twice the average abundance are defined as anomalous.

The heavy-mineral concentrates contained concentrations greater than 2,000 ppm (parts per million) of tin, the upper limit of detection. Greater than 2,000 ppm is considered anomalous in this study. The tin is most likely derived from the Swisher Mountain Tuff. Tin at this concentration in this sample medium is most likely contained in the mineral cassiterite, but cassiterite was not visually identified in the samples. Tin was not detected in the –80-mesh stream-sediment samples. Tin in heavy-mineral concentrates occurs in amounts that are large relative to the crustal abundance of tin (Sainsbury and Reed, 1973), but not unusual for concentrations from ordinary silicic volcanic rock sources. Anomalous concentrations of tin were found in scattered drainages, some of which are underlain exclusively by the Swisher Mountain Tuff, a likely source rock. Tin anomalies in drainages underlain mostly by basalt may result from eolian material blown in from the broad expanses of the Swisher Mountain Tuff that surround the basalt, or the anomalous tin could have been transported from the vitrophyre into the basalt by hydrothermal activity.

The stream-sediment samples delineate a zone of somewhat anomalous mercury concentrations (0.08 to 0.34 ppm) and arsenic concentrations (10 to 20 ppm) on the west side of the study area (fig. 2). The zone encompasses the west flank of the Horse Hill basalt vent and may have undergone weak epithermal alteration related to basalt volcanism at Horse Hill. The southwestern part of the anomaly may be due to weak epithermal alteration associated with the basalt vent at Summit 6518. Some rock samples from the western part of the study area contain relatively high and somewhat anomalous amounts of arsenic (to 10 ppm), cadmium (1.6 to 2.3 ppm), antimony (3 to 5 ppm), and mercury (to 0.09 pm).

An area of anomalous bismuth (2 to 4 ppm in stream sediment, 30 ppm in panned concentrate) is located in the southeastern part of the study area. Drainages in and near the area have anomalous concentrations of arsenic (13–18 ppm) and molybdenum (5 ppm). This area is underlain largely, but not exclusively, by the Swisher Mountain Tuff. The area may be a product of weak epithermal alteration associated with the Twin Butte basalt vent 1 mi southeast of the study area.

Low concentrations of silver (0.2 ppm) were found in basalt in a small area on the south flank of Horse Hill by the U.S. Bureau of Mines (Linne, 1987). This concentration of silver is twice the average abundance in basalt (Vinogradov, 1962) and is considered anomalous in this report. Analysis of the USGS stream-sediment sample of the area did not detect silver because the lower limit of detection is 0.5 ppm.

The concentrations of arsenic, bismuth, cadmium, antimony, mercury, molybdenum, and silver cited above are anomalous for the Swisher Mountain Tuff and basalt flows, but are not much higher than crustal abundances for these elements (antimony, Miller, 1973; arsenic, Gualtieri, 1973; bismuth, Hasler and others, 1973; cadmium, Wedow, 1973; mercury, Bailey and others, 1973; molybdenum, King and others, 1973; silver, Vinogradov, 1962).

The arsenic-mercury-antimony-silver element suite found in the western part of the study area suggests the occurrence of weak epithermal alteration processes, although broad zones of epithermally altered rocks were not found during this study. Devitrification and perlitification, common in many ash-flow tuffs, is widespread in the Swisher Mountain Tuff. These processes and vapor-phase recrystallization may have released minor elements for redistribution by weak hydrothermal systems that could have resulted from cooling of the welded tuff or from basalt volcanism at Horse Hill, Summit 6518, and Twin Buttes.

The anomalies reported by Gray and others (1983) and by Bukofski and others (1984) were not confirmed by this study at current U.S. Geological Survey levels of detection. The concentrations they report as anomalous for beryllium, copper, gold, manganese, nickel, silver, tungsten, uranium, and zinc are low and generally approximate crustal abundance. Their data suggest that most of the rocks of the study area have lower than average concentrations of these elements for the rock types present. If their data are indeed anomalous, they are largely consistent with a model of weak alteration associated with the basalt vents of the study area and vicinity.

Geophysical Studies

Gravity, aeromagnetic, aerial gamma-ray, and remote sensing studies were undertaken as part of the mineral resource evaluation of the study area. The geophysical data provide information on subsurface distribution of rock masses and the structural framework.

Aerial gamma-ray data were compiled by Geodata International, Inc. (1980) for the National Uranium Resource Evaluation (NURE) program of the Department of Energy. The coverage consists of five east-west flightlines at 3-mi intervals and one north-south flightline. The flightlines total about 43 mi in length. Flight altitudes ranged from 250 to 600 ft above the ground. Recordings were made of gamma-ray flux from radioactive isotopes of uranium, thorium, and potassium. Count rates show a strong correlation with the geology mapped by Walker and Repenning (1966). Count rates for all three isotopes were low over basalt flows and moderately high over rocks mapped as welded tuff, rhyolite flows, and dacite flows, with abrupt changes where the basalt is in contact with the other rock units. No site within the study area had count rates above the regional background level. Although no lines were flown over the basalt vent at Horse Hill, count rates for the vent area are expected to be low because basalt elsewhere in the area showed low counts.

A regional aeromagnetic survey was flown over the study area at a constant barometric elevation of 9,000 ft above sea level and a flightline spacing of 2 mi (U.S. Geological Survey, 1972). The low intensities of magnetic anomalies reflect a combination of low rock magnetization in the study area and high flight altitudes, averaging about 3,000 ft above the ground. The most conspicuous magnetic anomaly is a northwest-trending magnetic ridge along a line between Horse Hill and Twin Butte, 1 mi southeast of the study area. A local high is centered at the mafic vent at Twin Butte. A crest along the magnetic ridge is centered about 4 mi northwest of the vent at Horse Hill. Another magnetic ridge extends northeastward from Horse Hill. The complex magnetic highs may reflect apices of concealed Cenozoic intrusions. A northwest-trending magnetic trough includes local lows centered near the southwest and southeast corners of the study area. The magnetic lows may reflect underlying rocks with reversed magnetization, or rocks of low magnetization between rocks of higher magnetization.

The U.S. Geological Survey established 34 gravity stations within 3 mi of the border of the study area in 1986 (Plouff, 1987). These data were supplemented by data at three stations obtained from the National Geophysical Data Center (1984). Only two stations are located in the study area, and no stations are located along the west edge of the study area. A preliminary gravity map prepared from these widely spaced stations shows east-trending gravity contours that decrease southward about 13 milligals in 8 mi across the southern half of the study area and a small gravity high centered about 2 mi east and 4 mi south of the northern tip of the study area. A poorly defined gravity low near the southwest corner of the study area may coincide with the source of a magnetic low.

Linear features in Landsat multispectral scanner (MSS) images at the scale of 1:800,000 were mapped by photogeologic means for southeastern Oregon, and trend-concentration maps were made. Linear features are the topographic and spectral expression of rock fracture patterns and other structural and lithologic lineaments. This expression can be enhanced or subdued by scanner resolution, sun orientation, atmospheric phenomena, and vegetation. Analyses of linear features in conjunction with geologic and geophysical maps may reveal relations such as fracture control of mineralized areas.

Linear features of many orientations are generally well expressed on the surface in southeastern Oregon in terrains not underlain by volcanic rocks. Some areas have joint systems that are locally related to faults. Trend-concentration maps indicate that no concentration of linear features is expressed at the surface of the study area because the area is underlain by volcanic rocks. Two major concentrations lie to the northwest and southeast of the study area and consist of north-northeast-trending linear features with azimuths in the range N. 5°–35° E.

Mineral and Energy Resource Potential

Geologic and geochemical data indicate that the Upper West Little Owyhee Wilderness Study Area has low resource potential for mercury and silver-mercury deposits with a C certainty level. The resource potential for petroleum and natural gas is low with a B certainty level.

The investigations by the U.S. Geological Survey indicate that there is low mineral resource potential for mercury in the western part of the study area (fig. 2). This potential is indicated by somewhat anomalous concentrations of mercury, arsenic, cadmium, and antimony. A certainty level of C is assigned because the highest concentrations of mercury in stream-sediment and rock samples are not much greater than occur in ordinary volcanic rocks (Bailey, 1973), and no zones of altered rock were found in the well-exposed formations in the study area.

A low mineral resource potential for silver and mercury occurs in a small area in the central part of the study area on the south flank of Horse Hill. The low potential is indicated by the previously mentioned geochemical anomalies and by the slightly anomalous silver concentrations reported by Gray and others (1983) and Bukofski and others (1984). A certainty level of C is assigned because the highest concentrations of both metals are only slightly above their crustal abundances, the area of the anomaly is small (1.5 mi^2), and no zones of visibly altered rock were found.

Slightly anomalous concentrations of antimony, arsenic, bismuth, cadmium, and molybdenum in stream-sediment and rock samples may indicate weak epithermal alteration and possible mineralization. These elements can be indicative of gold, silver, and other metal deposits, but by themselves do not constitute potential resources.

Anomalous concentrations of tin (greater than 2,000 ppm) in panned concentrates occur in a few scattered drainages in amounts typical of silicic volcanic rocks such as the Swisher Mountain Tuff. Some of the tin is from drainages underlain by the Swisher Mountain Tuff. Tin also occurs in drainages largely underlain by basalt. In these areas the tin may have been hydrothermally redistributed from the Swisher Mountain Tuff or brought into the drainages in eolian deposits. The study area is judged to contain no potential for tin resources, certainty level D.

Wells were drilled for oil and gas 95 mi northeast of the study area in the western Snake River basin of Oregon and Idaho. Study of these wells and the regional geology led Newton and Corcoran (1963) to conclude that the depositional environments of the Snake River basin resemble other nonmarine basins that produce oil and gas and that hydrocarbons formed there during the late Miocene and early Pliocene. Late Miocene and early Pliocene time in the study area, however, was characterized by volcanism. Warner (1980) suggested that southeastern Oregon is underlain by Mesozoic and Tertiary rocks that contain potential source material for petroleum. However, pre-Tertiary rocks exposed in the region at South Mountain in Idaho and the Pueblo Mountains in Nevada and Oregon are metasedimentary and metavolcanic rocks that would not be good potential petroleum sources. During this study no surficial evidence was found that indicates the presence of hydrocarbons at depth. Any potential hydrocarbon reservoirs that might be present beneath the Swisher Mountain Tuff probably would have to be located by seismic surveys. Although it is likely that heat from volcanism in the area would have driven off any hydrocarbons, hydrocarbon concentrations below the Swisher Mountain Tuff cannot be ruled out. Fouch (1983) estimated the oil and gas potential of the study area to be low. Available geological and geophysical information indicates that the likelihood for occurrence of oil and gas within the study area is remote; for the purpose of this study the resource potential for oil and gas is considered low, certainty level B, for the entire study area.

No geothermal resources were found in or adjacent to the study area. The study area lies between areas of warm springs in the Owyhee Canyon near Three Forks, 26 mi northeast (Evans and others, 1987), and near McDermitt, 12 mi to the southwest (Muffler, 1978). Although the study area is in a region characterized by young silicic volcanic rocks, some parts of which offer likely geologic settings for magmatic heat reservoirs (MacLeod and others, 1976), the magma source of the Swisher Mountain Tuff is possibly in Idaho 35 mi northeast of the study area (Evans and others, 1987). The Swisher Mountain Tuff is of middle Miocene age and has probably cooled to ambient temperatures. The warm springs near Three Forks may be a result of young basalt volcanism. The study area, however, lacks extensive late Tertiary to Quaternary volcanism. The small basalt vents in and adjacent to the study area (Horse Hill, Summit 6518, Twin Buttes) have most likely cooled to ambient temperatures since Late Miocene to Early Pliocene. Therefore, there is no potential for geothermal resources in the study area with a certainty of D.

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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 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: Owyhee River Region, Idaho and Nevada

This volume was published as chapters A—H

U.S. GEOLOGICAL SURVEY BULLETIN 1719

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
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March 3, 1849