

# Mineral Resources of the Owyhee Canyon Wilderness Study Area, Malheur County, Oregon

U.S. GEOLOGICAL SURVEY BULLETIN 1719-E





Chapter E

Mineral Resources of the  
Owyhee Canyon Wilderness Study Area,  
Malheur County, Oregon

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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 : 1987

For sale by the  
Books and Open-File Reports Section  
U.S. Geological Survey  
Federal Center, Box 25425  
Denver, CO 80225

**Library of Congress Cataloging-in-Publication Data**

Mineral resources of the Owyhee Canyon Wilderness Study  
Area, Malheur County, Oregon.

U.S. Geological Survey Bulletin 1719-E

Bibliography

Supt. of Docs. No.: I 19.3:1719-E

1. Mines and mineral resources—Oregon—Owyhee Canyon  
Wilderness. 2. Owyhee Canyon Wilderness (Or.) I. Evans,  
James George, 1938- . II. Series.

QE75.B9 No. 1719-E

557.3 s

87-600297

[553'.09795'97]

## **STUDIES RELATED TO WILDERNESS**

### **Bureau of Land Management Wilderness Study Area**

The Federal Land Policy and Management Act (Public Law 94-379, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of part of the Owyhee Canyon Wilderness Study Area (OR-003-195), Malheur County, Oregon.



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

Mineral Resources of the  
Owyhee Canyon Wilderness Study Area,  
Malheur County, Oregon

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## SUMMARY

### Abstract

The part of the 180,680-acre Owyhee Canyon Wilderness Study Area (OR-003-195) on which mineral surveys were requested encompasses 152,040 acres in southeastern Malheur County, Oreg. In this report any reference to the Owyhee Canyon Wilderness Study Area refers only to that part of the wilderness study area on which mineral surveys were requested by the Bureau of Land Management. A mineral resource survey of the area included geologic mapping, a geochemical survey of stream sediments, and a study of mines, prospects, and mineralized areas. Subeconomic sand and gravel resources with a combined total of approximately 100,000,000 cubic yards were identified in three areas. Two areas have low potential for silver, lead, and tin, the northernmost one of which may be in epithermal veins associated with fault zones. One area has low potential for tin. One area has low potential for geothermal resources. The whole study area has unknown potential for oil and gas. The sand and gravel resources and stream gravels in the Owyhee River have unknown potential for gold.

### Character and Setting

The Owyhee Canyon Wilderness Study area is in the Owyhee Plateau southwest of Jordan Valley, southeastern Oregon (fig. 1). The area has a total relief of 2,400 ft and consists of broad flats and rolling hills cut by spectacular canyons incised to depths of 1,000 ft. The area is underlain by flat-lying volcanic, pyroclastic, and sedimentary rocks of middle Miocene (see appendixes for geologic time chart) through Holocene age. Rhyolitic welded ash-flow tuff and

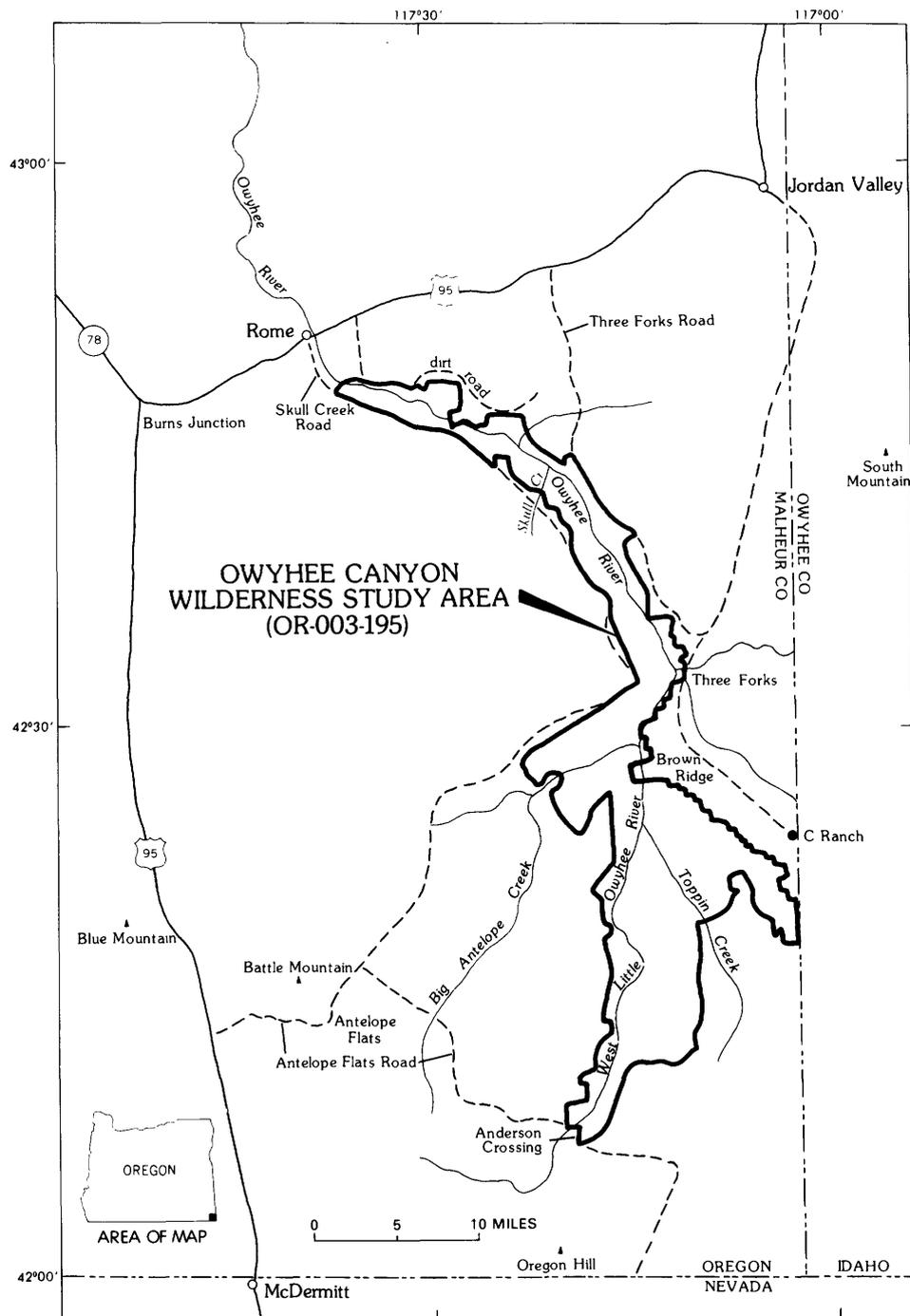
tuff breccia comprise the Swisher Mountain Tuff, the oldest and most abundant rock unit in the study area. Basalt overlies the rhyolite and forms low, rounded buttes that are probably the remains of shield volcanos. In the middle part of the area, the basalt and rhyolite are separated stratigraphically by a thin wedge of conglomerate, siltstone, tuff, and lacustrine deposits. In the northern part, the basalt is covered by conglomerate and silt. High-angle normal faults, ranging in age from Miocene through Holocene, are common in the northern part of the study area.

### Identified Mineral Resources

Approximately 100,000,000 yd<sup>3</sup> of subeconomic sand and gravel resources were identified. Four of six samples of this material contain traces of gold. No metallic mineral resources were identified during this study. Several outcrops of lacustrine tuffaceous sediments were analyzed for zeolites; no zeolites were detected. Of 126 rock samples, 51 samples, or about 40 percent, contain detectable levels of either gold, silver, arsenic, antimony, or sulfur. Of the 51 samples, 13 contain gold, 33 contain silver, 13 contain arsenic, 1 contains antimony, and 2 contain sulfur. However, these values were generally low and do not indicate the presence of resources. Oil and gas leases have been let, and subsequently terminated, on parts of the study area, but no geophysical exploration or drilling has been done. Trace amounts of gold were found in gravel samples from the Owyhee River.

### Mineral Resource Potential

Two areas of the Owyhee Canyon Wilderness Study Area have low mineral resource potential for silver, lead, and tin. These commodities are associated with weak epithermal zones and faults close



**Figure 1.** Index map showing location of the Owyhee Canyon Wilderness Study Area, Malheur County, Oregon.

to basaltic vents that are just outside the study area (Grassy Mountain, Sacramento Hill, fig. 2). The area associated with Black Butte basaltic vent has low potential for tin. Deposits of subeconomic sand and gravel resources and stream gravels along the Owyhee River have unknown potential for gold. Low potential for geothermal resources occurs along the

Owyhee Canyon south of Three Forks where several warm springs flow into the Owyhee River. These springs appear to be connected by faults to the chain of basaltic vents that trend northwest from Warm Springs Canyon through Grassy Mountain, both have low potential for geothermal energy because of relatively low temperature.

## INTRODUCTION

### Area Description

The Owyhee Canyon Wilderness Study Area (OR-003-195) covers 152,040 acres along the Owyhee River, parts of the West Little Owyhee River and Big Antelope Creek, and adjacent parts of the Owyhee Plateau southwest of Jordan Valley, Oreg. (fig. 1). The terrain is generally flat to gently rolling, rising gradually from 3,400 ft at the north end near Rome, Oreg., to 5,800 ft at the south end at Anderson Crossing. Deeply incised canyons, especially the spectacular Owyhee Canyon, with maximum relief of 1,100 ft, are cut into the plateau. The arid climate supports sagebrush, rabbit brush, and sparse native grasses, replaced locally by seedings of crested wheatgrass (by the U.S. Bureau of Land Management). Scattered juniper trees grow above 5,000 ft on the plateau; small groves of juniper are present in the Owyhee Canyon near Three Forks. Aspen and cottonwood grow near springs and in sheltered parts of the canyons. Riparian areas support mostly grasses, rushes, and sedges. The study area is used for cattle grazing and also supports mule deer, pronghorn antelope, wild horses, bighorn sheep, cougar, coyote, black bear, and numerous species of birds, small mammals, and reptiles, including the western diamondback rattlesnake.

Motor vehicle access to and within the area to many localities on the canyon rims is by dirt roads and jeep trails along the study area boundary. The main access roads southward from the Rome area include the Skull Creek Road, an unnamed dirt road on the northeast rim of the Owyhee Canyon, and the Three Forks Road, which connects U.S. Route 95 to Three Forks. Access to the northeast rim of the Owyhee Canyon south of Three Forks is by an unnamed dirt road over Brown Ridge toward C Ranch near the Idaho State line. The southern part of the area is best reached by the Antelope Flats Road, which joins U.S. Route 95 15 mi north of McDermitt, Nev. This road crosses the West Little Owyhee River at Anderson Crossing. Several jeep trails branch from this road to provide access to points in the southern and southwestern parts of the study area.

### Previous and Present Investigations

The Owyhee Canyon Wilderness Study Area includes parts of the following 7.5-minute quadrangles: Scott Reservoir, Dry Creek Rim, Little Grassy Mountain, Indian Fort, Skull Creek, White Horse Butte, Squaw Flat, Three Forks, No Crossing Crossing, Drummond Basin, Deacon Crossing, Rawhide Springs, Rawhide Pocket, Beaver Charlie Breaks, Guadalupe Meadows, Stoney Corral, and Oregon Butte. The study area is in the west half of the Jordan Valley 1<sup>0</sup> by 2<sup>0</sup> sheet. Reconnaissance geologic mapping of this area was published by Walker and Repenning (1966) at the scale of 1:250,000 and Walker (1977) at the scale of 1:500,000 and by Evans (1987) at the scale of 1:62,500. Other workers (Hart, 1982; Hart and Aronson, 1983; Hart and Mertzman, 1983; Gray and others, 1983; Hart and others, 1984) studied the

stratigraphy and chemistry of volcanic rocks from southeastern Oregon and adjacent regions, including the Owyhee Canyon Wilderness Study Area.

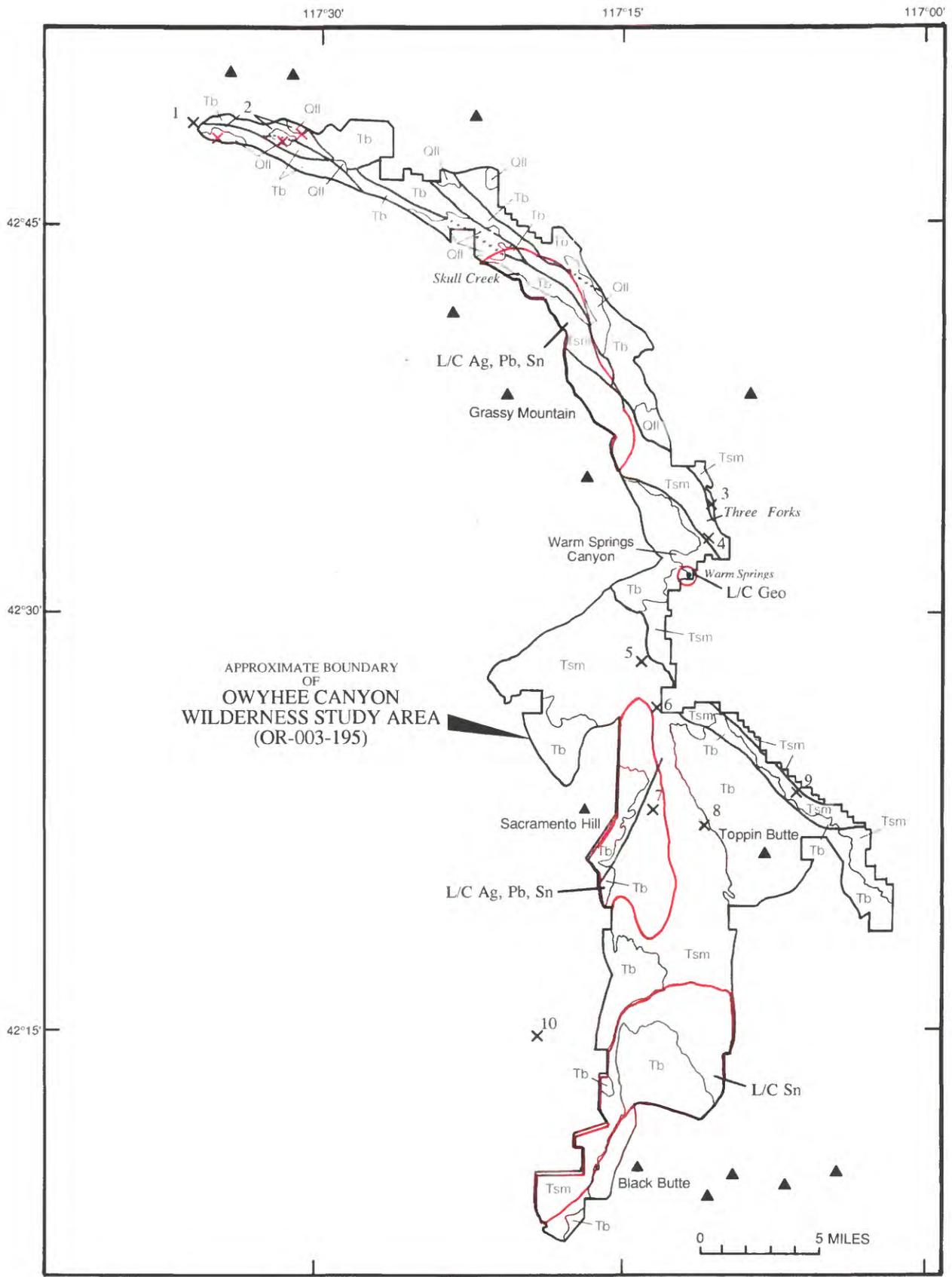
The U.S. Geological Survey carried out field investigations in the study area during 1984 and 1985. This work included geologic mapping at the scale of 1:24,000 for later compilation at 1:62,500 and geochemical sampling. Rock samples were collected for petrographic and chemical analysis in order to determine if the rocks showed evidence of hydrothermal mineralizing systems. The analytical data from 202 stream-sediment and 149 heavy-mineral concentrate samples are in Erickson and others (1986). The geologic field observations and geochemical data were evaluated with the information obtained by the U.S. Bureau of Mines to assess identified mineral resources (known) and the mineral resources potential (undiscovered) in the study area.

## APPRAISAL OF IDENTIFIED RESOURCES

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

### Methods

Malheur County records and BLM master title plats were examined for mining claims in the study area, and USBM library materials and production records were studied for additional information. A field search was conducted for mines, prospects, or mineralized zones in or near the study area. Thirteen alluvial (placer) and 148 rock (lode) samples were collected. Seven grab samples of alluvium consisting of from one to ten 14-in. pans each were collected from some of the larger gravel bars on the Owyhee and West Little Owyhee Rivers. Six bulk placer samples consisting of 1.2 ft<sup>3</sup> each of loose gravel were taken from 6-ft vertical parts of three gravel deposits; these samples were concentrated in a sluice and analyzed at the Bureau of Mines, Western Field Operations Center placer laboratory. None of the bulk placer samples were from material at bedrock. All placer samples were further concentrated in the laboratory. Gold was extracted from the concentrates by handpicking and amalgamation. The concentrates were also checked for radioactivity and fluorescence. Rock (lode) samples were assayed for gold and silver by fire assay, or by fire assay and atomic absorption. Concentrations of other metallic elements, including arsenic, antimony, mercury, molybdenum, and uranium, were determined by atomic absorption. Several samples from each locality were analyzed for 40 elements (Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Pd, Pt, Sb, Sc, Si, Sn, Sr, Ta, Te, Ti, V, Y, Zn, and Zr) by semiquantitative spectrography to detect elements of possible significance. If anomalous amounts of economic elements were indicated, the sample was analyzed by more precise methods. A complete description of sampling and analysis techniques is given in Linne (1986). Detailed information is available from the U.S. Bureau of



**Figure 2.** Mineral resource potential and generalized geology of the Owyhee Canyon Wilderness Study Area, Malheur County, Oregon.

## EXPLANATION

	Area of low mineral resource potential--See appendix for definition of levels of mineral resource potential and certainty of assessment
$\times^2$	Identified resource--See table 1 for description
Commodities	
Ag	Silver
Pb	Lead
Sn	Tin
Geo	Geothermal
Geologic map units	
Qfl	Fluviatile and landslide deposits (Quaternary)
Tb	Basalt (Tertiary)
Tsm	Swisher Mountain Tuff (Miocene)
—	Contact
—	Fault--Dotted where concealed
$\times^3$	Prospect--See table 1 for description
▲	Unnamed peak

Figure 2. Continued.

Mines, Western Field Operations Center, E. 360 Third Avenue, Spokane, WA 99202.

### History and Production

No mines are located within or adjacent to the study area. The closest operating mine is the DeLamar mine approximately 30 mi northeast of the area. This mine has produced silver and gold since 1977. Within the McDermitt caldera complex, 30 mi southwest of the study area, 15,185 flasks of mercury were produced from the Bretz mine between 1931 and 1968, 12,367 flasks were produced from the Opalite mine between 1927 and 1944, and 114,000 flasks were produced from the Cordero mine between 1933 and 1970. Until January 20, 1987 mercury was produced at the McDermitt mine, which has the largest deposit of mercury in North America (Rytuba and Glanzman, 1979, p. 103, 113). There is no projected date for reopening at this time.

Several mining companies have filed claims and explored the Rome beds deposits 15 mi northeast of the study area for zeolites and fluorspar. Limited amounts of zeolites were mined by Norton Company during the 1960's (Santini and LeBaron, 1982, p. 1).

Several mining companies have conducted geochemical sampling near Oregon Hill (fig. 1) and in the study area, where anomalous concentrations of

gold, tungsten, silver, and tin were identified by Gray and others (1983) and Bukofski and others (1984).

Prospecting for gem-grade chalcedony occurred at two sites (Nos. 1 and 8, table 1, fig. 2). Neither site has had any recent work.

As of 1984, there were no active mining claims in the study area. The most recent activity (1982) was confined to oil and gas leases, which covered 21,000 acres of the northern part of the study area. These leases were terminated by 1984. No seismic refraction studies have been conducted, nor have any wells been drilled in or near the area.

### Mineral Resources

Prospects and mineralized areas examined during this study are shown in figure 2 and described in the appendixes (see also Linne, 1986). Included in these sites are those identified by Gray and others (1983) and Bukofski and others (1984) as anomalous for gold, lead, silver, fluorine, molybdenum, or tin. Samples of altered and brecciated zones, chalcedony, and opalized material (fig. 2, Nos. 1, 4, 5, 7, 8, and 9) were collected near several of these anomalies. Of 116 rock samples from sites 7, 8, and 9, 42 samples, or about 36 percent, contain gold concentrations as much as 0.02 troy ounce per ton (oz/ton), silver as much as 0.2 oz/ton, or arsenic as much as 29 parts per million. Nine samples of altered opalized vitrophyre and vitrophyre breccia from three sites in the West Little Owyhee River and Big Antelope Creek areas contain no significant mineral values. A trace of gold was found in six reconnaissance placer samples from the Owyhee River at Five Bars (table 1, No. 6).

Tuffs and tuffaceous sediments are present in the northern part of the study area and the area around Three Forks (fig. 2, No. 3). The sediments in the northern part of the area are equivalent to the zeolite-rich, informally named Rome beds. None of the 23 samples from outcrops of the tuffs around Three Forks contain zeolites. Nine composite samples prepared from 20 of these samples and 1 chip sample were analyzed for gold, silver, arsenic, mercury, and molybdenum. Seven samples contain gold between 0.017 and 0.075 ppm, six contain traces of arsenic (3-5 ppm), and three contain silver at 10.5 oz/ton (325 ppm), 2.5 oz/ton (77 ppm), and 2.1 ppm. (Note: the high silver concentrations could not be duplicated on these samples by the laboratory of the U.S. Geological Survey in Denver (J.D. Hoffman, written commun., 1986)). No antimony, mercury, or molybdenum were detected.

Areas of Quaternary sediments (Walker and Reppenning, 1966) in the northern part of the study area were examined to determine the quantity of sand and gravel present. Three major areas were identified (fig. 2, No. 2) where a total of approximately 100 million yd<sup>3</sup> of subeconomic resources of sand and gravel cover about 1,200 acres.

Platy, rhyolitic welded tuff that could be used as decorative building stone is present over an area of about 2 mi<sup>2</sup> west of Black Butte at the south end of the study area. The rock weathers to rectangular plates approximately 2 in. thick with sides ranging from approximately 1 to 4 ft long. It has no unique

properties and since abundant, better quality material exists closer to markets, this material is not classified as a resource.

## ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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### Geology

The Owyhee Canyon Wilderness Study Area is underlain by a flat-lying sequence of rhyolitic welded tuff and basalt and by poorly consolidated to unconsolidated sedimentary and tuffaceous rocks that range in age from Middle Miocene to Holocene. Geology shown in figure 2 is simplified from Evans (1987).

The oldest exposed rock unit in the study area is a rhyolitic, welded ash-flow tuff, named the Swisher Mountain Tuff by Eckren and others (1984, p. 24-32). These rocks were also described by Walker and Repenning (1966), Hart (1982, p. 218-220), and Hart and Aronson (1983). Along the Owyhee Canyon the Swisher Mountain Tuff consists of at least two cooling units. The rock is typically purplish gray to reddish brown on fresh surfaces, weathers to brown or reddish brown, is usually finely laminated, and has 10 to 50 percent phenocrysts as much as 0.2 in. across. The phenocrysts are mostly alkali feldspar (orthoclase, anorthoclase, sanidine) and plagioclase ( $An_{30}$ ) and include minor amounts of quartz, pigeonite, hypersthene, magnetite, and zircon. The cryptocrystalline to glassy matrix consists of glass shards and deformed pumice fragments. In places the rock has abundant cavities as much as 2 ft long and 2 in. wide parallel to the laminae. The cavities are partly filled with white chalcedony and translucent bluish-gray hyalite. Parts of the unit consist of dark-gray to black, massive or layered vitrophyre, red, black, and yellow welded tuff breccia, and gray massive rhyolite. Minimum thickness of the Swisher Mountain Tuff in the study area is estimated at 1,000 ft. This estimate is greater than the thickness inferred for this formation by Ekren and others (1984, pl. 2). They suggested that these rocks were erupted from a vent at Juniper Mountain, southwest Idaho. Geophysical evidence presented below, however, suggests that the Swisher Mountain Tuff was deposited as a result of caldera-forming eruptions. Potassium-argon ages on samples of the Swisher Mountain Tuff range from 12.5 to 14.6 million years (Ma) (Hart and Aronson, 1983; Neill, 1975), or middle Miocene (Palmer, 1983).

A sedimentary and pyroclastic unit that is generally very poorly exposed lies above the Swisher Mountain Tuff in the study area from about 5 mi north to 10 mi south of Three Forks. The basal part of the unit is commonly a moderately to poorly consolidated pale-brown conglomerate containing 10 to 20 percent rounded to angular pebbles of reddish-brown rhyolitic tuff similar to the Swisher Mountain Tuff, and less-abundant, highly polished chert pebbles from sources outside the study area. Upward in the section the beds

are generally progressively less consolidated and consist of pale-brown to white siltstone, lacustrine deposits, and rhyolitic tuff. White limestone and opaline chert lenses are present near the top of the unit. North of Three Forks, rhyolitic tuff as much as 60 ft thick is interbedded with basalt flows indicating that rhyolitic and basaltic extrusion overlap in time. The upper 10 ft of the sedimentary and pyroclastic unit was baked red in places, where the rocks were relatively dry when they were covered by basalt. In other places, the upper contact is marked by hyaloclastite where the basalts covered a wet playa. The unit is as much as 300 ft thick. J.P. Bradbury (written commun., 1986) suggested a middle to late Miocene fossil age for a sample of diatomaceous chert from the upper part of the unit. A middle Miocene age is most likely for this unit as the youngest potassium-argon age for the underlying welded tuff below it and the oldest potassium-argon age for the overlying basalt are also middle Miocene.

Dark-gray to black, generally vesicular basalt unconformably overlies the Swisher Mountain Tuff and the overlying sedimentary and pyroclastic unit. The uppermost 100 ft of basalt at the north end of the study area overlies part of the Rome beds, a siltstone, lacustrine, and tuff sequence (Walker and Repenning, 1966). The basalts have been described by Walker and Repenning (1966), Hart (1982, p. 42-74), Hart and Mertzman (1982, 1983), and Hart and others (1984). They contain less than 20 percent phenocrysts of labradorite and olivine partly altered to iddingsite. Diktytaxitic texture is common. In places the basalts have as much as 20 percent vesicles, and locally contain abundant white calcareous and zeolitic amygdules. Hart (1982, p. 357-368) determined that most of the basalts in the study area are tholeiites, or transitional to alkaline olivine basalt. One sample is a low potassium-high alumina olivine basalt. The basalts total as much as 600 ft thick, including lenses of interflow sediments as much as 30 ft thick, along Owyhee Canyon near the north end of the study area. The low, rounded buttes common near the study area are shield volcanos from which the basalt, at least the younger basalt, was extruded. Nine potassium-argon ages of basalt from the study area and vicinity were determined by Hart (1982, p. 45-46) and Hart and Mertzman (1983, p. 17); ages range from 11.5 to 1.5 Ma or late middle Miocene to Pleistocene (Palmer, 1983). An older potassium-argon age of  $13.8 \pm 1.5$  Ma, or middle Miocene, was reported from basalt located about 0.3 mi north of the study area (Fiebelkorn and others, 1983). Most dated samples in the study area are late Miocene. Regionally, the basalt appears to have been extruded during three main pulses: 0 to 2.5 Ma, 3.5 to 6 Ma, and 7 to 10 Ma (Hart, 1982, p. 93; Hart and others, 1984, p. 193), all of which are present in the study area.

Pleistocene sedimentary deposits mostly northwest of Skull Creek consist of gravel, silt (possibly loess), and alluvial fan or delta deposits that overlie the basalt and rhyolite. The gravel contains rounded to angular clasts, as much as 1 ft across, of rhyolitic welded tuff, basalt, and polished chert pebbles. Deposits are as thick as 100 ft in the study area and were laid down by an ancestral Owyhee River system before the canyon was incised.

Holocene deposits include unconsolidated landslide debris, alluvium along the Owyhee River and its tributaries, and older alluvium covering remnant stream terraces along the Owyhee River. The landslide deposits, covering as much as several square miles of the inner Owyhee Canyon, are most common in the north half of the study area between Three Forks and Skull Creek. The landslides are mostly basalt boulders, but include small playas formed in closed depressions on the landslides. The other Holocene deposits consist of sand and silt containing pebbles and cobbles of rhyolitic welded tuff, basalt, and chert.

Closely spaced, generally steep, normal faults strike northwest to east, close to the trend of the Owyhee Canyon (Evans, 1987). These faults were influential in localizing the Owyhee River along its present course. Stratigraphic separations along the faults vary from a few feet to a few hundred feet. The most conspicuous offset occurs 8 mi north of Three Forks where a fault runs along the canyon bottom. The opposing canyon rims differ in elevation by 300 ft, but the stratigraphic separation is more than 1,000 ft (downthrown block on the northeast). The southern part of the study area along the West Little Owyhee River and Toppin Creek (fig. 1) has few faults that penetrate the basaltic rim rocks. Some of the faulting may be related to upwarping of the terrane in response to emplacement of basalt prior to venting. In the case of the Grassy Mountain vent system, however, the vents may have been localized along preexisting northwest-trending faults. Ages of the faults range from middle Miocene to Pleistocene.

## Geochemical Studies

Reconnaissance geochemical studies were based on analysis and evaluation of 202 stream sediments, 149 heavy-mineral concentrates from stream sediments, and 22 rock samples. The stream sediment and heavy-mineral concentrate analyses represent the chemistry of the rock material eroded from the drainage basin upstream from each sample site; moreover, analyses of heavy-mineral concentrates provide data about the chemistry of heavy minerals in the rock. Analytical data and a description of the sampling and analytical techniques used are given in Erickson and others (1986).

All samples were analyzed for 31 elements by a six-step semiquantitative emission spectrographic method (Myers and others, 1961); the heavy-mineral concentrate samples were analyzed for 31 elements by a different six-step semiquantitative emission spectrographic method (Grimes and Marrantzino, 1968). In addition, all the stream-sediment samples were analyzed for antimony, arsenic, bismuth, cadmium, and zinc by inductively coupled argon plasma-atomic emission spectrometry (Crock and others, 1983) using a modification of an atomic absorption technique (Viets, 1978). These analyses are used to identify drainages with anomalous concentrations of metals.

Anomalous values were determined by a combination of inspection of histograms and percentiles of the data.

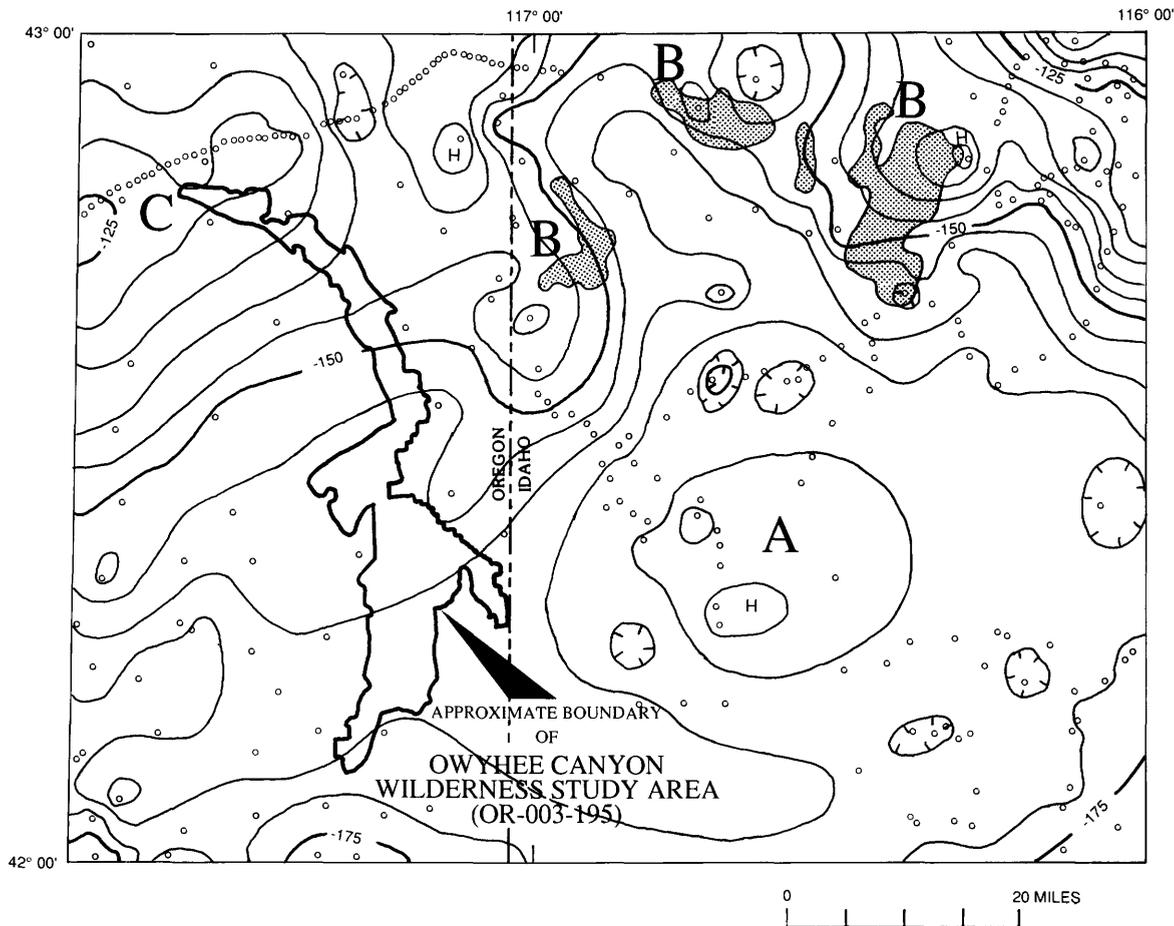
Anomalous values of arsenic, bismuth, cadmium, lead, and silver in stream sediment samples, and tin in panned concentrate samples are present in the study area in three areas: (1) near Skull Creek (bismuth, cadmium, lead, silver, tin); (2) along the West Little Owyhee River south of Big Antelope Creek (arsenic, cadmium, lead, silver, tin); and (3) along the West Little Owyhee River at the south end of the study area (arsenic, cadmium, tin). The anomalous values of arsenic, bismuth, cadmium, lead, and silver in stream-sediments are statistically derived, are close to the lower limits of detection, and are not much greater than crustal abundances (arsenic, Gualtieri, 1973, p. 53; bismuth, Hasler and others, 1973, p. 96; cadmium, Wedow, 1973, p. 107; lead, Morris and others, 1973, p. 317; silver, Heyl and others, 1973, p. 584). Tin in heavy-mineral concentrates occurs in the mineral cassiterite in amounts that are large relative to the crustal abundance of tin (Sainsbury and Reed, 1973, p. 641), but not unusual for concentrations from ordinary silicic volcanic rock sources.

Broad zones of epithermally altered rocks were not found during this study although slight argillic alteration and silicification (deposition of chalcedony) were observed in moderately well lithified tuff breccia that is present between ash-flow sheets south of Three Forks. Clearly, devitrification has also occurred, as feldspar microlites are present in vitrophyre of the Swisher Mountain Tuff (Eckren and others, 1984, fig. 10). The slight alteration and devitrification may have been enough to release minor amounts of certain metals for transport and distribution by weak hydrothermal systems.

The proximity of the weak geochemical anomalies and the basalt vents strongly suggest that the anomalous areas are due to weak hydrothermal systems developed on the margins of the basaltic vents, which are outside the study area: (1) Grassy Mountain and associated vents, (2) Sacramento Hill, and (3) Black Butte. Some of the weak mineralization in the northernmost area may be a result of leakage of hydrothermal fluids along fault zones. The tin at Grassy Mountain and Sacramento Hill could have been transported from a source in subsurface rhyolitic welded tuff during mineralization, or could have been reconcentrated from Pleistocene sedimentary (eolian?) deposits that are mostly eroded. The tin in the third anomaly is from the welded tuff, and may have been epithermally concentrated in that area.

Low-level lead anomalies in the Big Antelope Creek area and near Anderson Crossing appear to be unrelated to other mineralization. These anomalies could be due to bullets or lead shot, as these areas have easy road access and are attractive to hunters.

The anomalies inferred by Gray and others (1983) and by Bukofski and others (1984) were not duplicated in this study at current U.S. Geological Survey levels of detection. The anomalous values they report for arsenic, barium, beryllium, cobalt, copper, fluorine, lead, manganese, mercury, molybdenum, nickel, tin, tungsten, uranium, and zinc are low and generally approximate crustal abundance. Their anomalies would be largely consistent with the model of weak mineralization associated with the three basalt vent systems mentioned above and with an additional zone of weak mineralization near the Toppin Butte basalt vent.



### EXPLANATION

-  Gravity contour--In milligals. Hachured in direction of low gravity value
-  Gravity station
- A** Area of anomaly discussed in text
- H** Gravity high
-  Outcrops of Idaho batholithic rocks

**Figure 3.** Complete Bouguer gravity map of the Owyhee Canyon Wilderness Study Area and vicinity, Malheur County, Oregon.

No evidence was found bearing on whether any of these weakly mineralized zones comprise leakage anomalies from more mineralized rock at depth.

### Geophysical Studies

Gravity and magnetic studies were undertaken as part of the mineral resource evaluation of the study area. The geophysical data provide information on the subsurface distribution of rock masses and the structural framework.

Gravity data were obtained from files maintained by the Defense Mapping Agency of the Department of Defense and supplemented by additional data obtained in 1985. Bouguer gravity anomaly values were computed using the 1967 gravity formula (International Association of Geodesy, 1967) and a reduction density of  $2.67 \text{ g/cm}^3$  (grams per cubic centimeter). Terrain corrections were made by computer for a distance of 167 km (100 mi) from the station using the method of Plouff (1977).

The area of extreme southwestern Idaho and southeastern Oregon is characterized by intermediate

Bouguer values between -150 and -175 mGals over a predominantly rhyolitic terrane (fig. 3). Gravity values decrease southeastward across the area shown in figure 3 due to a greater thickness of low density material, presumably rhyolitic tuffs and welded tuffs. The low culminates east of 117° long where a roughly circular low gravity anomaly 20 to 25 mi in diameter (fig. 3, A) suggests an underlying volcanotectonic depression that may have been a source of the rhyolitic pyroclastic rocks at the surface, including the Swisher Mountain Tuff.

Higher gravity values (fig. 3, B) are associated with outcrops of rocks of the Idaho batholith east of the study area. The increasing gravity values over the northern part of the study area (fig. 3, C) suggest that similar rocks may be present in the surface here.

Aeromagnetic data west of 117° long is shown on a U.S. Geological Survey map (1972). Flightlines are east-west at approximately 2- to 3-mi spacing and 9,000 ft barometric elevation. The magnitude of the aeromagnetic anomalies, range of total magnetic intensity values, and wavelengths of the anomalies are similar over a broad area of mixed rhyolites and basalts in southeastern Oregon and southwestern Idaho. In and near the study area magnetic lows seem to be associated with some areas of fracturing and faulting, particularly in the basalt unit, and suggest destruction of magnetic minerals by weathering or weak hydrothermal alteration along faults or near basalt vents. Rocks below the exposed Miocene volcanics may contribute to the aeromagnetic anomalies; the anomalies are not clearly related to potential mineral resources.

### Mineral and Energy Resource Potential

Geologic studies, geochemical sampling, and examination of prospects, altered rock, and placer deposits indicate that the Owyhee Canyon Wilderness Study Area contains areas of low resource potential for silver, lead, and tin in zones of weak epithermal alteration. Anomalous concentrations of arsenic, bismuth, and cadmium indicate zones of weak epithermal alteration and mineralization. The presence of these rare elements in high concentrations could accompany precious and other metallic deposits, but would not themselves be likely to constitute a minable resource. Thus, two areas have low potential for silver, lead, and tin and one area has potential for tin in epithermal zones, with certainty level C.

Several warm springs (88-95 °F) with an estimated combined flow of 1,000 gallons per minute (Waring, 1965, p. 41) issue from cracks in the Swisher Mountain Tuff near the mouth of Warm Springs Canyon south of Three Forks. These springs lie along the northwest trend of the Grassy Mountain vent system and are close to faults that may have controlled the locations of these vents. Deep circulation of water along the faults in an area of slightly elevated heat flow would explain the occurrence of the warm springs. However, it seems likely that the faults near the springs are connected with the Grassy Mountain vent system. The slightly elevated heat flow may be from a still-cooling basaltic magma at depth. This relation between the springs and the vents would be an

attractive hypothesis if the basalt on Grassy Mountain and related flows could be shown to be very young. The basalt at the base of the mountain is Miocene age (7-10 Ma) (Hart, 1982, p. 46), but a possible remnant vent crater, now a shallow playa, at the top of the mountain, suggests that the uppermost basalt is millions of years younger than the basalt at its base. If extrusive activity at the Grassy Mountain vent system had continued until late Pliocene or Pleistocene time, the warm springs could be reflecting residual heat from this volcanism.

The warm springs south of Three Forks are 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). However, most silicic magma sources in this part of southeastern Oregon are much older than 2 Ma, and probably have cooled to near ambient temperatures. The warm springs in the study area may be a result of young basaltic volcanism or of deep circulation in a region of slightly elevated heat flow. The small basalt vents, most likely extending from great depth, are poor targets for geothermal heat production, however. Therefore, the potential for geothermal resources south of Three Forks is low with certainty level C.

North of the study area in the western Snake River basin of Oregon and Idaho, wells were drilled for oil and gas. Study of these wells and the regional geology led Newton and Corcoran (1963) to conclude that the depositional environments of the basin resembled 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 basaltic volcanism. Warner (1980) suggested that southeastern Oregon is underlain by deposits of Mesozoic and Tertiary age that contain potential source material for petroleum genesis. 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 do not appear to be potential petroleum sources. During this study no surficial evidence was found for inferring the presence of hydrocarbons at depth. Any hydrocarbon reservoirs that might be present beneath the middle Miocene Swisher Mountain Tuff probably would have to be located by geophysical methods.

Surface evidence of oil or gas resources was not found in or near the study area, although hydrocarbon concentrations at depth below the Swisher Mountain Tuff cannot be ruled out. The potential for oil and gas in the entire study area is unknown.

According to Bureau of Mines' data, four of six samples taken from the sand and gravel deposits contained traces of gold in concentrations less than 0.000125 oz/yd<sup>3</sup>. Because of limitations placed on the sampling program by the BLM, these deposits could not be adequately evaluated. Therefore these areas have been assigned unknown potential for gold. Trace amounts of gold, found in gravel samples at Five Bars, suggest that the Owyhee River gravels have unknown potential for gold.

Platy welded tuff (Swisher Mountain Tuff) at the south end of the study area is potentially useful as

decorative building stone. However, it is structurally inferior to abundant andesite northwest of the study area that has been used for this purpose and is 15 mi closer to a major highway. If the andesite were depleted, the welded tuff might be considered an alternative source of decorative stone.

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## APPENDIXES

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## DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

### Definitions of Mineral Resource Potential

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

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

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

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

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

### Levels of Certainty

↑ LEVEL OF RESOURCE POTENTIAL	U/A	H/B HIGH POTENTIAL	H/C HIGH POTENTIAL	H/D HIGH POTENTIAL
	UNKNOWN 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
	A	B	C	D
		LEVEL OF CERTAINTY →		

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

### Abstracted with minor modifications from:

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# RESOURCE/RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES		UNDISCOVERED RESOURCES		
	Demonstrated		Inferred	Probability Range	
	Measured	Indicated		Hypothetical	Speculative
<b>ECONOMIC</b>	Reserves	Inferred Reserves			
<b>MARGINALLY ECONOMIC</b>	Marginal Reserves	Inferred Marginal Reserves			
<b>SUB-ECONOMIC</b>	Demonstrated Subeconomic Resources.	Inferred Subeconomic Resources			

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

## GEOLOGIC TIME CHART

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

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

<sup>1</sup>Rocks older than 570 Ma also called Precambrian, a time term without specific rank.

<sup>2</sup>Informal time term without specific rank.

TABLE 1. Prospects and mineralized areas in the Owyhee Canyon Wilderness Study Area

Map No. fig. 2)	Name	Summary	Workings	Sample and resource data
1	Unnamed prospect	Chalcedony vein as much as 1 ft thick exposed intermittently for 1,000 ft.	Hand dug pits	One sample contains 0.3 oz/ton silver and 29 ppm arsenic. Chalcedony excavated from pits.
2	Sand and gravel	Three gravel deposits covering about 1,200 acres. Terraces of smooth, well-rounded unsorted sand and gravel as much as 3 in. in diameter. The material consists of basalt, rhyolite, chert, and quartzite.	Bulldozer scrapes	Approximately 100 million yd <sup>3</sup> of sand and gravel at the prospects. Four of six samples contain trace of gold (less than 0.000125 oz/yd <sup>3</sup> ).
3	Three Forks, tuff	Light-gray, buff, green, or brown tuff and tuffaceous sediments with minor limonite and some clay. Outcrops as thick as 60 ft are exposed intermittently for approximately 3 mi.	None	Twenty-three samples along the 3-mi intermittent exposure: 21 chip, 1 grab, and 1 select. All analyzed for zeolites. No zeolites were detected. Nine composite samples representing 20 chip samples were analyzed for gold, silver, arsenic, antimony, mercury, and molybdenum. Six of these composites and one chip sampled contain as much as 0.075 ppm gold and three contain 10.4 and 2.5 oz/ton and 2.1 ppm silver. Six samples contain traces (3-5 ppm) of arsenic. Of seven samples that contain silver or arsenic, five also contain gold. One sample contains gold, silver, and arsenic.
4	Owyhee River-Three Forks	Altered vitrophyre, opal, tuff, and exposed thickness of 45 ft.	None	Three chip samples contain no detectable mineral values.
5	Antelope Creek	Altered vitrophyre and altered rhyolite; exposed thickness of 50 ft.	None	Two chip samples contain no detectable mineral values.
6	Five Bars	Gravel bars 3 to 10 ft thick	None	Six grab samples: all contain a trace of gold. Gold is extremely fine and flat indicating long distance transport.
7	West Little Owyhee River	Vitrophyre breccia, rhyolite, altered vitrophyre with limonite and chalcedony and stream gravel.	None	Two grab samples of stream gravel contain no detectable gold. Three samples of altered vitrophyre and vitrophyre breccia from one site contain 0.1 oz silver per ton and two of these samples contain a trace gold.
8	Toppin Creek	Altered vitrophyre as thick as 5 ft with pods, veinlets, and a thin capping of chalcedony and jasperoid geodes. Vitrophyre occurs within rhyolite with minor limonite and is exposed for 1.5 mi.	Shallow bulldozer scrapes in chalcedony.	Fifty-three samples: 32 chip, 18 select, 3 random chip. Two select samples, one of chalcedony and one altered vitrophyre, contain a trace of gold. Seven chip samples of chalcedony, vitrophyre, altered vitrophyre, and rhyolite contain a trace of silver; three select samples of chalcedony and rhyolite contain 22 to 29 ppm arsenic.
9	Upper Owyhee River	Altered and brecciated vitrophyre and rhyolite breccia with jasperoid geodes, overlain by partially opalized, tuffaceous sandstone and siltstone. Vitrophyre is underlain by and locally contains pods of rhyolite. Main exposure is approximately 150 ft thick. Intermittent exposure of 8 mi.	None	Sixty samples along a 3-mi intermittent exposure: 29 chip, 26 random chip, 5 select. Five chip and one select sample of altered vitrophyre and rhyolite contain trace to 0.02 oz/ton gold. Nine chip samples of altered vitrophyre, tuffaceous sediments, and rhyolite; six random chip samples of altered vitrophyre, rhyolite, and vitrophyre breccia; and three select samples of altered vitrophyre, and rhyolite contain trace silver. One 2-ft chip sample of opalized siltstone contains 17.8 ppm arsenic; one 23-ft chip sample of altered vitrophyre and rhyolite contains 7 ppm arsenic; and one select sample of chalcedony contains 15.3 ppm arsenic.
10	Pole Creek	Rhyolite outcrop.	None	One sample contains 4.2 ppm uranium.



