Mineral Resources of the Fifteen Mile Creek, Oregon Canyon, Twelve Mile Creek, and Willow Creek Wilderness Study Areas, Malheur and Harney Counties, Oregon

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Chapter B

Mineral Resources of the Fifteen Mile Creek, Oregon Canyon, Twelve Mile Creek, and Willow Creek Wilderness Study Areas, Malheur and Harney Counties, Oregon

By JOCELYN A. PETERSON, JAMES J. RYTUBA, DONALD PLOUFF, THOMAS L. VERCOUTERE, ROBERT L. TURNER, *and* DON L. SAWATZKY
U.S. Geological Survey

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U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1742

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
TROUT CREEK MOUNTAINS REGION, OREGON

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of parts of the Fifteen Mile Creek (OR–003–156), Oregon Canyon (OR–003–157), Twelve Mile Creek (OR–003–162), and Willow Creek (OR–003–152) Wilderness Study Areas, Malheur and Harney Counties, Oregon.

FIGURES

CONTENTS

Mineral Resources of the Fifteen Mile Creek, Oregon Canyon, Twelve Mile Creek, and Willow Creek Wilderness Study Areas, Malheur and Harney Counties, Oregon

By Jocelyn A. Peterson, James J. Rytuba, Donald Plouff, Thomas L. Vercoutere, Robert L. Turner *and* Don L. Sawatzky
U.S. Geological Survey

Andrew M. Leszcykowski, Thomas J. Peters, Steven W. Schmauch, *and* Richard A. Winters
U.S. Bureau of Mines

SUMMARY

Abstract

The parts of the Fifteen Mile Creek (OR–003–156), Oregon Canyon (OR–003–157), Twelve Mile Creek (OR–003–162), and Willow Creek (OR–003–152) Wilderness Study Areas for which mineral surveys were requested by the U.S. Bureau of Land Management encompass 51,290, 42,900, 25,340, and 26,130 acres, respectively, in southeastern Oregon. Throughout this report, reference to those specific areas, or to the "study areas" refers only to those parts of the wilderness study areas for which mineral surveys were requested. Field work was carried out during the summer of 1986 by the U.S. Bureau of Mines and the U.S. Geological Survey to appraise the identified (known) resources and assess the mineral resource potential (undiscovered) of the study areas.

The four contiguous study areas lie near mineralized calderas to the south; however, none of the study areas have any identified resources. The southern part of the Fifteen Mile Creek study area has low potential and the southern part of the Oregon Canyon study area has moderate and low potential for mercury and uranium resources near ring fractures around a caldera. In the Oregon Canyon study area, the tuff of Oregon Canyon and the caldera rim have low potential for gold and silver resources in epithermal veins. The southern parts of the Fifteen Mile Creek, Oregon Canyon, and Willow Creek and the northwestern part of the Oregon Canyon study areas have low potential for antimony, bismuth, mercury, silver, molybdenum, and zinc resources in epithermal deposits. Tin geochemical anomalies in the southeastern part of the Oregon Canyon, the southwest corner of the Fifteen Mile Creek, and the southeast corner of the Willow Creek study areas suggest a terrane having low potential for tin resources of unknown origin, possibly related to the basaltic rocks in those parts of the three study areas. All four study areas have low potential for zeolite resources because of their volcanic terrane. The northernmost part of the Twelve Mile Creek and the northwest tip of the Fifteen Mile Creek study areas have low potential for pumice as scattered fragments in tuff. The four areas have a low potential for geothermal energy resources because of their proximity to warm-water wells and springs nearby. There are no oil and gas leases in the areas, and all areas have low potential for resources of oil and gas. The tuff of Trout Creek Mountains, exposed in all the study areas, has a low potential for resources of light rare-earth elements and zirconium in local accumulations of aenigmatite, a sodium-iron-titanium mineral. This same rock unit is locally attractive enough for use a decorative building stone; therefore, this unit has low potential for decorative stone resources. Sand and gravel accumulations are present locally in all the study areas, but material of similar quality is available closer to potential markets.

Manuscript approved for publication July 22, 1988.

Character and Setting

The Fifteen Mile Creek (OR–003–156), Oregon Canyon (OR–003–157), Twelve Mile Creek (OR–003–162), and Willow Creek (OR–003–152) Wilderness Study Areas are located in southeastern Oregon between 7 and 35 mi northwest of McDermitt, Nev. (fig. 1). The regional topography is characterized by plateaus and mountainous terrain dissected by deep canyons. The study areas lie between the Whitehorse caldera and two calderas (Long Ridge and Washburn) of the McDermitt caldera complex (fig. 1; Rytuba and McKee, 1984), which are sources of the tuffs found within the study areas. Rocks of the study areas consist mostly of welded to nonwelded rhyolitic ash-flow tuffs and mafic to felsic flows.

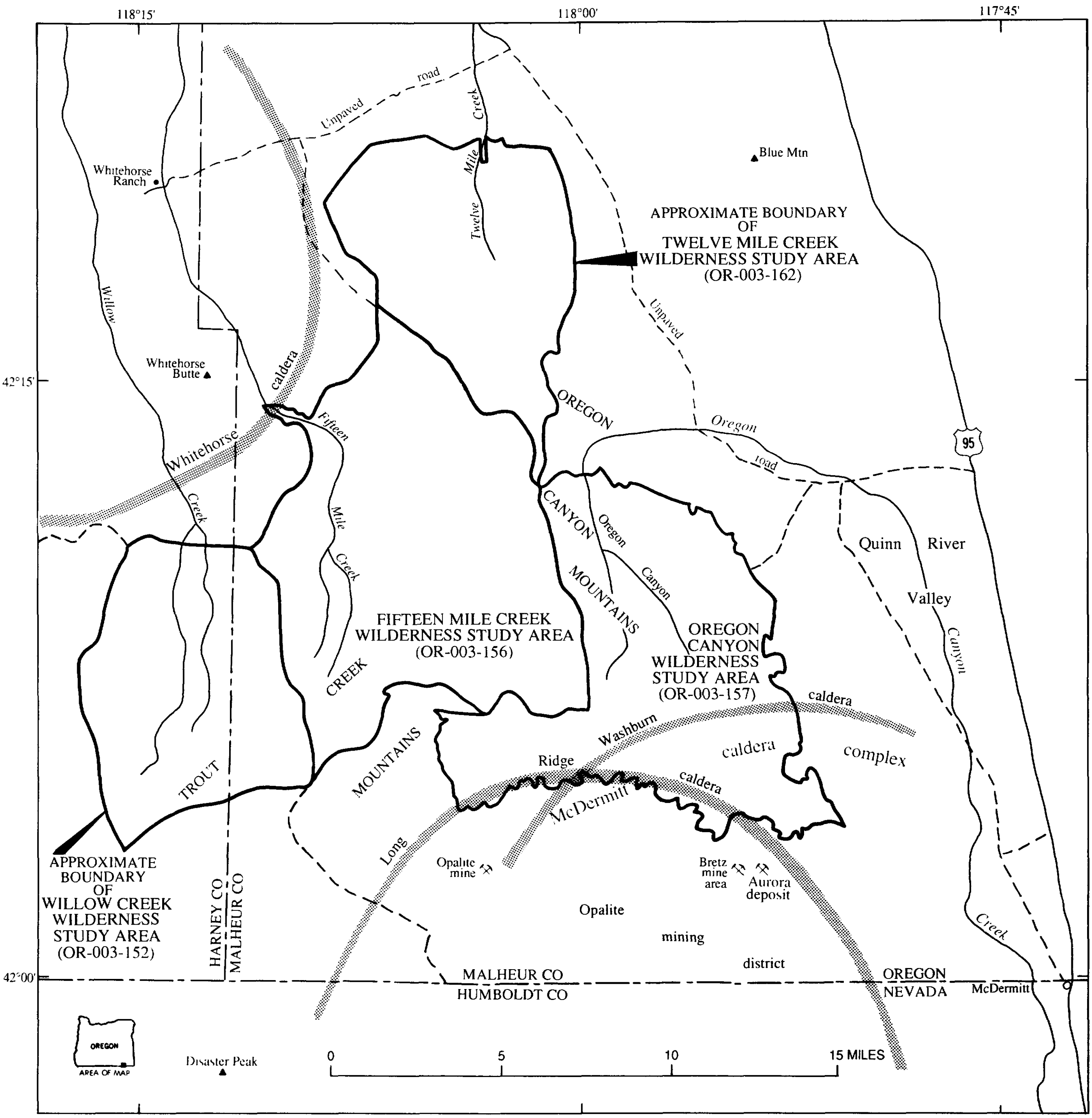


Figure 1. Index map showing location of Fifteen Mile Creek, Oregon Canyon, Twelve Mile Creek, and Willow Creek Wilderness Study Areas, Malheur and Harney Counties, Oregon.

Identified Resources and Mineral Resource Potential of the Fifteen Mile Creek Wilderness Study Area

No identified mineral resources are present in the Fifteen Mile Creek study area. Sand and gravel accumulations along creeks are not considered to be resources because material of similar quality is available closer to prospective markets. Four prospect pits (fig. 2) in the southeast corner of the area are the only known mining claims or prospects. The Opalite mining district (fig. 1) in the McDermitt caldera complex is south of the study area; however, the geologic environment of the district does not extend into the study area. The southern part of the study area has low potential for mercury and uranium resources associated with the caldera complex (fig. 2). The entire study area has low potential for zeolite resources in the volcanic rocks. The southern part of the study area has low potential for antimony, bismuth, mercury, silver, molybdenum, and zinc resources in epithermal deposits. Geochemical anomalies for tin in the southwest corner of the area suggest low potential for tin resources of unknown origin possibly in the basaltic rocks. The northwest tip of the study area has low mineral resource potential for pumice. The tuff of Trout Creek Mountains has low resource potential for decorative building stone and for rare-earth elements and zirconium. The entire area has low potential for geothermal energy resources. There are no oil and gas leases in the study area, and the area has low potential for resources of these commodities.

Identified Resources and Mineral Resource Potential of the Oregon Canyon Wilderness Study Area

No mineral resources were identified in the Oregon Canyon Wilderness Study Area. The study area contains no mining districts, although the Opalite mining district, within the McDermitt caldera complex, is adjacent to the south. There are 8 inactive claims, recorded in 1914, in the southeastern part of the study area and 110 current claims in the eastern part. Concentrations of metallic minerals in the study area are small and of low grade. Occurrences of nonmetallic commodities are too low grade, small, and far from foreseeable markets to be mined. Sand and gravel along creek beds are not classified as identified resources because equally suitable material is available closer to prospective markets. Rocks adjacent to and near to the caldera rim, in the southern part of the study area, have moderate and low potential, respectively, for both mercury and uranium resources (fig. 3). This caldera rim area and the tuff of Oregon Canyon have low potential for gold and silver resources in epithermal veins. The southern and northwestern parts of the Oregon Canyon study area have low resource potential for antimony, bismuth, mercury, silver, molybdenum, and zinc in epithermal deposits. Tin geochemical anomalies in the southeastern part of the study area suggest a low resource potential for tin in deposits of an unknown type possibly related to basaltic rocks. The entire study area has low potential for zeolite resources. The area has low resource potential for both geothermal energy and oil and gas. The tuff of Trout Creek Mountains has low resource potential for decorative building stone and for rare-earth elements and zirconium.

Identified Resources and Mineral Resource Potential of the Twelve Mile Creek Wilderness Study Area

There are no identified mineral resources in the study area. Sand and gravel along creek beds do not constitute resources because suitable material is readily available closer to prospective markets. There is low potential for zeolite resources throughout the study area in the volcanic rocks, and the northernmost part of the area has low potential for pumice resources (fig. 4). The resource potential for oil and gas and for geothermal energy is low. The tuff of Trout Creek Mountains has low resource potential for decorative building stone and for rare-earth elements and zirconium.

Identified Resources and Mineral Resource Potential of the Willow Creek Wilderness Study Area

Identified mineral resources, mining activity, and oil and gas leasing are not present in the study area; however, evidence for fault-zone-related epithermal mineralization is present at two localities. Minor amounts of sand and gravel along narrow creek beds are too small and remote from markets to constitute resources. The southern part of the area has low mineral resource potential for antimony, bismuth, mercury, silver, molybdenum, and zinc in epithermal deposits (fig. 5). The southeast corner has geochemical anomalies that suggest low resource potential for tin in deposits of an undetermined kind possibly in basaltic rocks. The entire area has low potential for zeolite resources. The entire area has low potential for both geothermal energy and oil and gas. The tuff of Trout Creek Mountains has low resource potential for decorative building stone and for rare-earth elements and zirconium.

INTRODUCTION

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

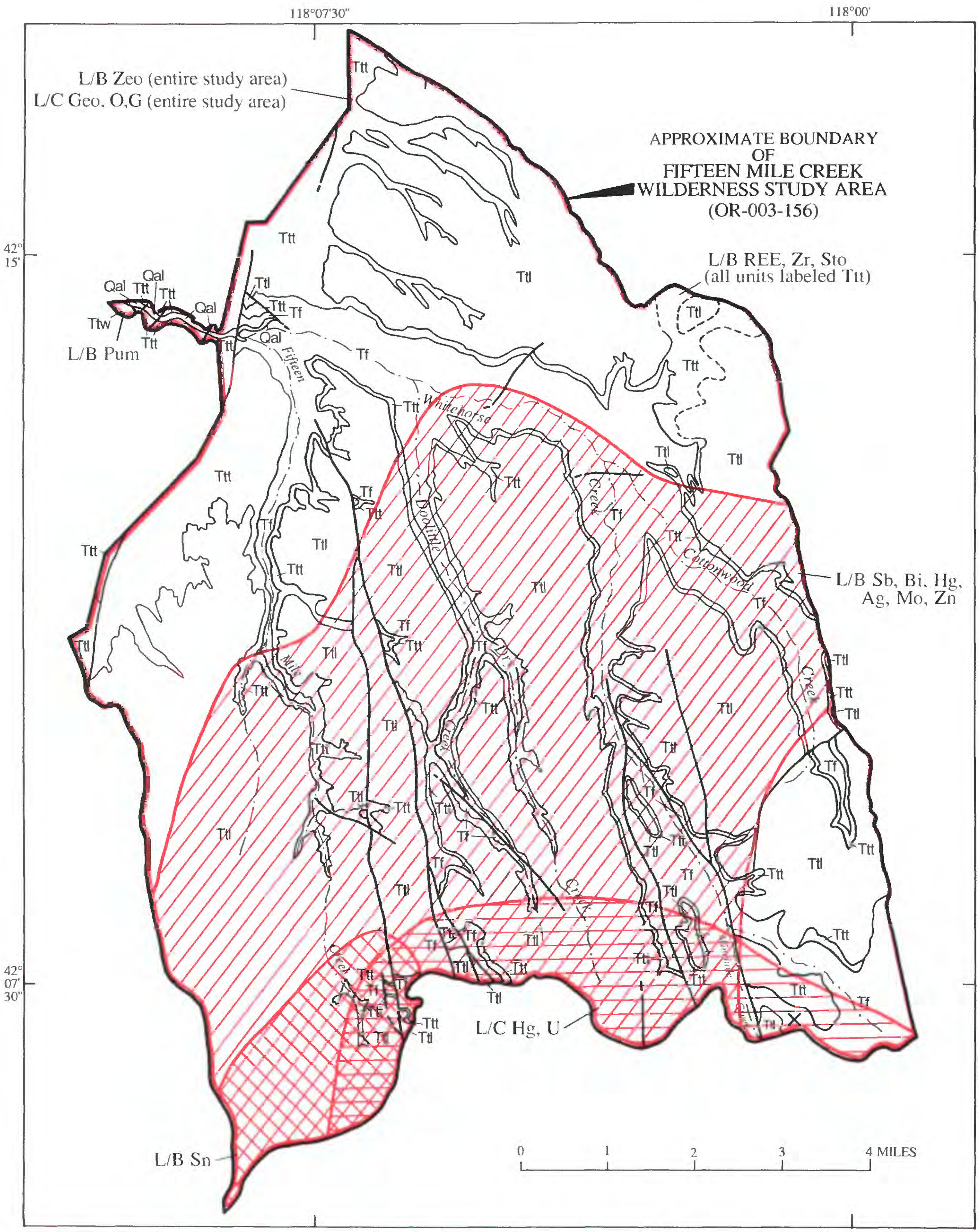


Figure 2. Generalized geology and mineral resource potential of Fifteen Mile Creek Wilderness Study Area, Malheur County, Oregon.

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

EXPLANATION

Geologic terrane having low mineral resource potential (L) for Sb, Bi, Hg, Ag, Mo, and Zn in epithermal vein deposits

Geologic terrane having low mineral resource potential (L) for Sn

Geologic terrane having low mineral resource potential (L) for Hg and U in caldera-related deposits

Geologic terrane having low mineral resource potential (L) for Zeo, Geo, Pum, and O,G

Ttt — Geologic terrane having low mineral resource potential (L) for REE, Zr, and Sto

Levels of certainty of assessment

B	Data only suggest level of potential
C	Data give good indication of level of potential

Commodities

Ag	Silver	Sb	Antimony
Bi	Bismuth	Sn	Tin
Geo	Geothermal	Sto	Decorative building stone
Hg	Mercury	U	Uranium
Mo	Molybdenum	Zeo	Zeolite minerals
O,G	Oil and gas	Zn	Zinc
Pum	Pumice	Zr	Zirconium
REE	Rare-earth elements		

Description of map units

Qal	Alluvium (Quaternary)
Ttw	Tuff of Whitehorse Creek (Tertiary)
Ttl	Tuff of Long Ridge (Tertiary)
Ttt	Tuff of Trout Creek Mountains (Tertiary)
Tf	Basaltic andesite, andesite, and rhyolite flows (Tertiary)

Contact—Dashed where approximately located

Fault—Dashed where approximately located

× Prospects

Figure 2. Continued.

Character and Setting

The Fifteen Mile Creek (OR–003–156), Oregon Canyon (OR–003–157), Twelve Mile Creek (OR–003–162), and Willow Creek (OR–003–152) Wilderness Study Areas are located in southeastern Oregon between 7 and 35 mi northwest of McDermitt, Nev. (fig. 1). They cover 51,290, 42,900, 25,340, and 26,130 acres, respectively. The areas lie in the northwestern part of the Basin and Range physiographic province in a region characterized by north-trending horst-graben structures, calderas, and thick volcanic sequences of Tertiary age (see geologic time chart in appendixes). Steep topography is common; elevations range from 7,949 ft in the Oregon Canyon Mountains to about 4,700 ft in the northwestern parts of the Twelve Mile Creek and Willow Creek study areas. The study areas are accessible by numerous graded dirt roads branching off of U.S. Highway 95 to the east and Nevada Highway 140 to the south. Dirt roads separate each of these four contiguous areas, but some interior parts of the areas are difficult to reach. The climate is semiarid with moderately warm to hot summers and cold winters; most precipitation falls during the winter.

Vegetation in the study areas belongs to the sagebrush steppe community of the Great Basin Floristic Province. A sagebrush steppe, sometimes referred to as the sagebrush-grass vegetation type, consists of a series of generally treeless, shrub-dominated communities. The dominant shrub in the study areas consists of big sagebrush (*Artemisia tridentata*), and the dominant grass is bluebunch wheatgrass (*Agropyron spicatum*). Idaho fesque (*Festuca idahoensis*) becomes the dominant grass in drier situations. Stream banks in the study areas support characteristic riparian vegetation, including typical trees of the Great Basin: aspen (*Populus tremuloides*), juniper (*Juniperus* spp.), cottonwood (*Populus fremontii*), and oak (*Quercus* spp.). Rush- (*Juncus* spp.-) dominated meadows and seeps represent a common wetland vegetation community found in the study areas.

Previous Investigations

The geology of the Opalite mining district was first described by Yates (1942). The district includes the Opalite and Bretz mercury deposits and the Aurora uranium deposit, all located about 1.5 mi south of the Oregon

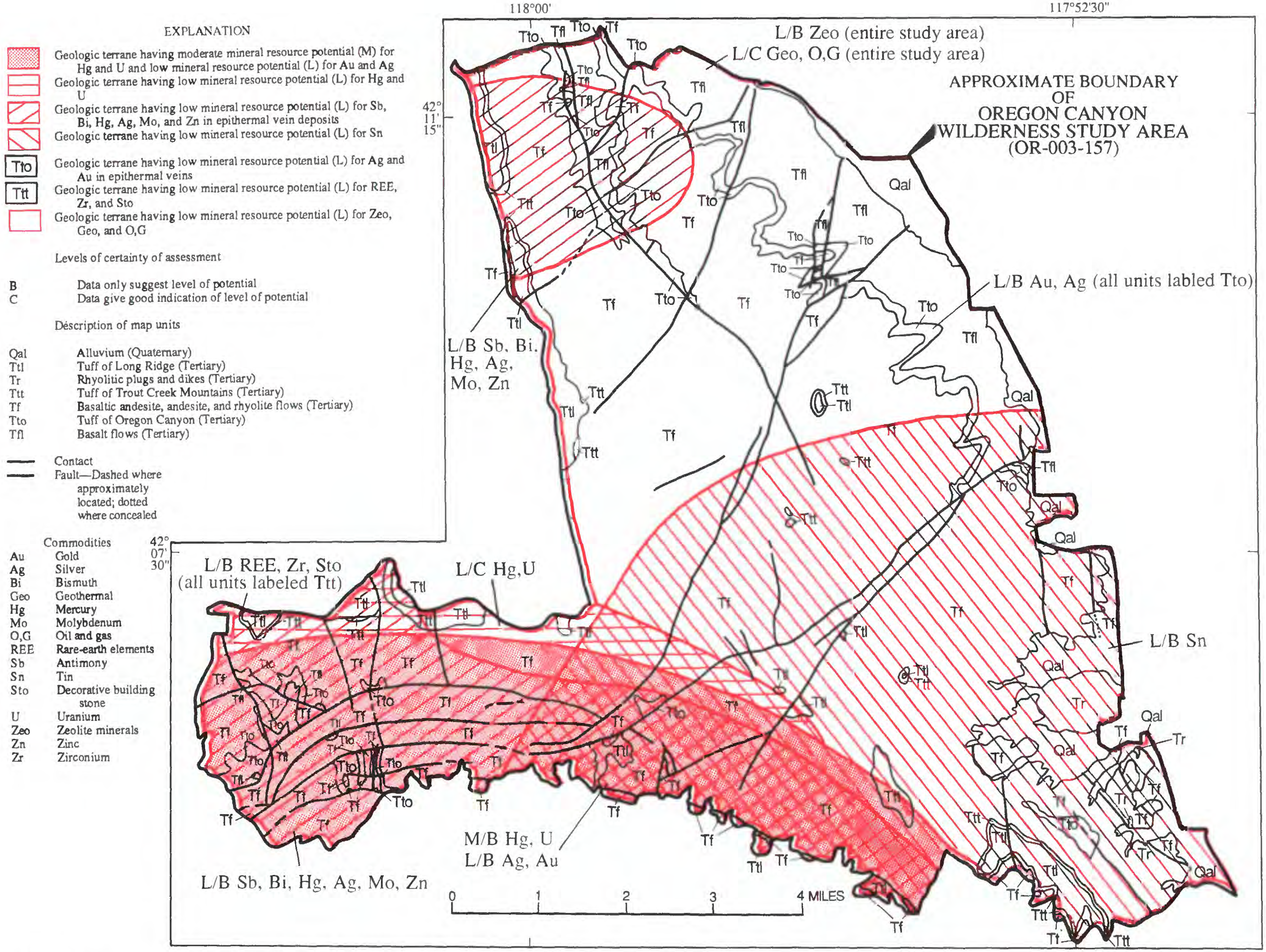


Figure 3. Generalized geology and mineral resource potential of Oregon Canyon Wilderness Study Area, Malheur County, Oregon.

Canyon study area. Reconnaissance geologic maps of the Adel and Jordan Valley 1° by 2° quadrangles, which include the study areas, were published by Walker and Repenning (1965, 1966). Initial detailed mapping within the McDermitt caldera complex was provided by Greene (1972, 1976); revised and more detailed geologic mapping and interpretations of the McDermitt caldera complex were presented by Rytuba (1976), Rytuba and Conrad (1981), and Rytuba and McKee (1984). Several quadrangles covering the study areas have been mapped at a scale of 1:24,000 (Rytuba and others, 1983a, b, c, d; Rytuba and Curtis, 1983; Peterson and Tegtmeyer, 1987; J.J. Rytuba and others, unpub. mapping, 1980). Rytuba and Glanzman (1979) and Glanzman and Rytuba (1979) investigated mineral deposits associated with the McDermitt caldera complex, and Rytuba and others (1981) presented a detailed geologic history of the Whitehorse caldera and discussed associated mineral deposits.

Present Study

The USBM searched published literature, Harney and Malheur County mining claim records, USBM Mineral Industry Location System records, and BLM mining and mineral lease records. Information from USBM, Oregon Department of Geology and Mineral Industries (DOGAMI), and other production records was also used. Fieldwork carried out in 1986 included a search for mines, prospects, mining claims, and mineralized areas within and adjacent to the study areas. Samples were taken of potentially mineralized rocks for geochemical assay and of alluvial material primarily for placer analysis to detect free gold and other valuable heavy minerals. Analytical data are on file at the U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Ave., Spokane, WA 99202.

The USGS mapped the geology of the quadrangles that include the study areas from about 1980 to 1987 (see previous section) and in 1986 collected rock and stream-sediment samples for geochemical analysis. Gravity data were collected to augment previously published information; aeromagnetic and radiometric interpretations are based on published regional data.

Acknowledgments

Personnel from the Oregon Canyon, Stoddard, and Whitehorse Ranches kindly allowed us passage across their lands to gain access to parts of the study areas and provided indispensable information and directions. J.J. Gray of DOGAMI provided helpful advice and information on the study areas. George Brown and Mark Hosket of the BLM, Burns, Oreg., provided logistical and land status information. The BLM mineral staff in Vale, Oreg., particularly William Holsheimer and Wylmoth Jones, provided helpful information about access to the areas and about mineral deposits of the region. C.S. Harwood and S.L. Jones assisted with the field work by the U.S. Geological Survey.

APPRAISAL OF IDENTIFIED RESOURCES OF THE FIFTEEN MILE CREEK WILDERNESS STUDY AREA

By Andrew M. Leszcykowski
U.S. Bureau of Mines

Mining and Exploration History

A search of Malheur County, State, and Federal mining records revealed no mines, claims, or mineral leases within the study area. Four prospect pits, which appear to be relatively old, were found near the junction of Minehole and Whitehorse Creeks (fig. 2) during a search of the area (Leszcykowski, 1987). The study area lies immediately north of the Opalite mining district (Benson, 1956), where five mercury mines are located. The Ruja, Cordero, and McDermitt mines lie about 15 mi southeast of the study area, and the Opalite and Bretz mines are about 5 mi south-southeast.

Results of Investigation

No mineral resources were identified during this study. None of the four rock samples collected from the prospect pits near the confluence of Minehole and Whitehorse Creeks contain anomalous elemental concentrations. Of the nine alluvial samples collected, one from just outside the northwest boundary of the area contained a small flake of gold; the others had none. No samples have indications of metal concentrations, but four samples contain minor amounts of moonstone (the potassium feldspar adularia). However, the moonstones are too small to be considered gem quality, and the source of the alluvial moonstone was not found. Sand and gravel accumulations in the lower canyons of the Fifteen Mile, Doolittle, Whitehorse, and Cottonwood Creeks have no local markets because road metal and gravel for road base are available closer to areas of probable use. There are no oil or gas leases within the study area. All of the mines in the nearby Opalite mining district are located in the McDermitt caldera complex, which does not extend into the study area.

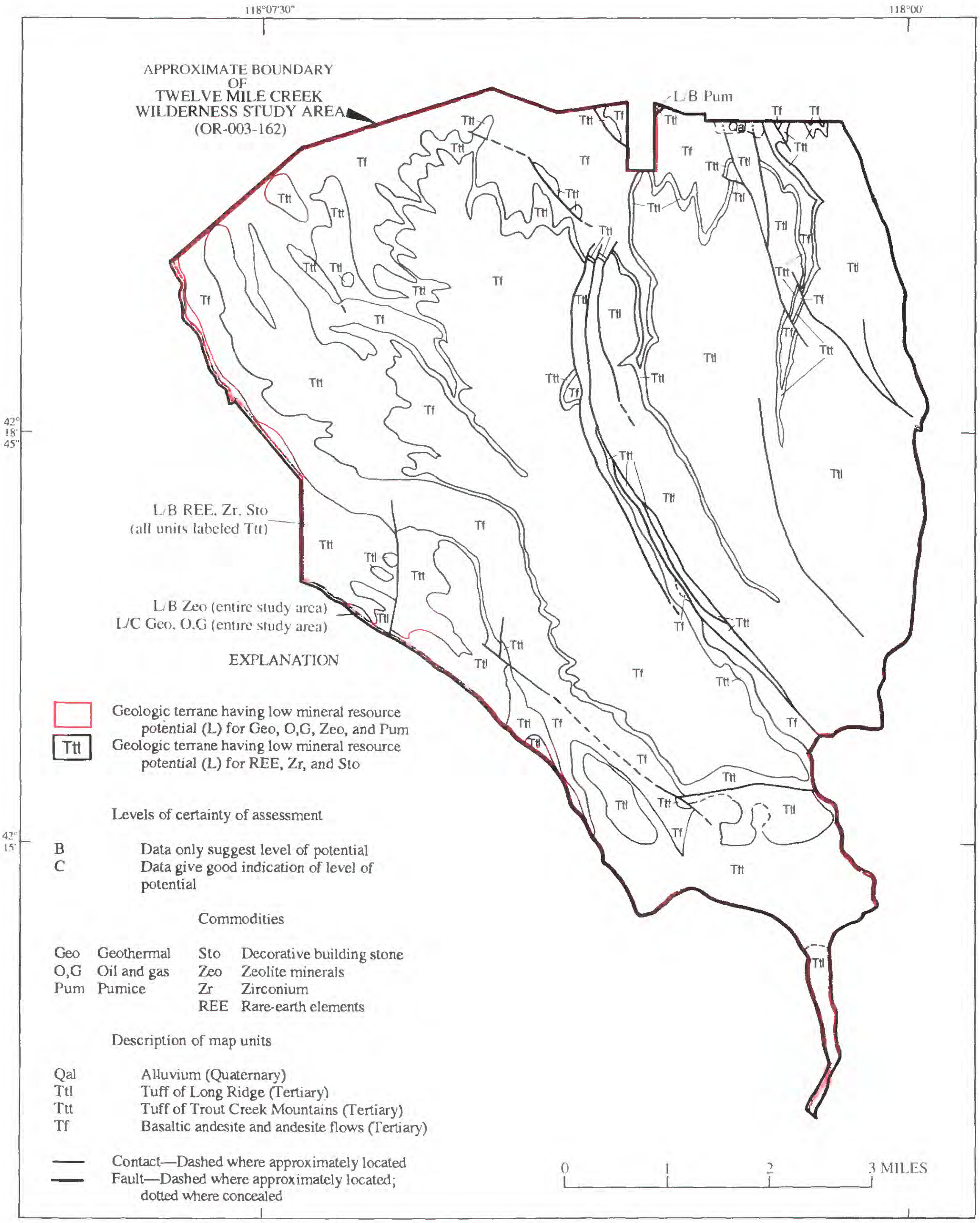
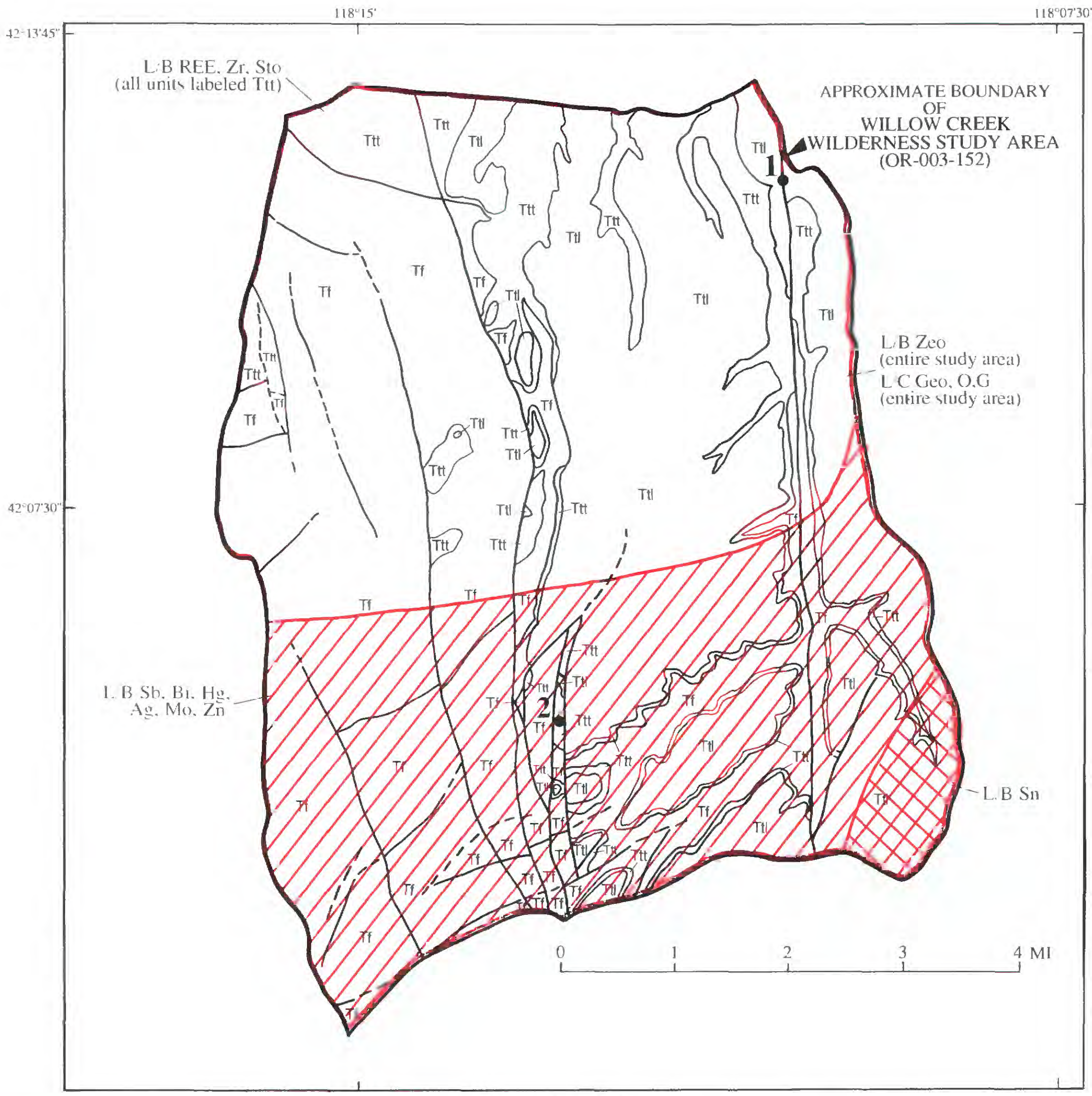


Figure 4. Generalized geology and mineral resource potential of Twelve Mile Creek Wilderness Study Area, Malheur County, Oregon.



EXPLANATION

- Geologic terrane having low mineral resource potential (L) for Sb, Bi, Hg, Ag, Mo, and Zn
- Geologic terrane having low mineral resource potential (L) for Sn
- Geologic terrane having low mineral resource potential (L) for Zeo, Geo, and O,G
- Ttt — Geologic terrane having low mineral resource potential (L) for REE, Zr, and Sto

Levels of certainty of assessment

- B — Data only suggest level of potential
- C — Data give good indication of level of potential

Commodities

Ag	Silver	Sb	Antimony
Bi	Bismuth	Sn	Tin
Geo	Geothermal	Sto	Decorative building stone
Hg	Mercury	Zeo	Zeolite minerals
Mo	Molybdenum	Zn	Zinc
O,G	Oil and gas	Zr	Zirconium
REE	Rare-earth elements		

Description of map units

- Ttl — Tuff of Long Ridge (Tertiary)
- Ttt — Tuff of Trout Creek Mountains (Tertiary)
- Tf — Basaltic andesite, andesite, and rhyolitic flows (Tertiary)

- Contact
- Fault—Dashed where approximately located
- 1● Sample locality noted in text

Figure 5. Generalized geology and mineral resource potential of Willow Creek Wilderness Study Area, Harney and Malheur Counties, Oregon

APPRAISAL OF IDENTIFIED RESOURCES OF THE OREGON CANYON WILDERNESS STUDY AREA

By Richard A. Winters
U.S. Bureau of Mines

There are no identified resources in the Oregon Canyon Wilderness Study Area. There were 8 inactive claims recorded in 1914 that are present in the southeastern part of the study area, and 110 current claims are in the eastern part. No mines or mineralized structures were observed during the field studies. The study area contains no mining districts, but the Opalite mining district located within the McDermitt caldera complex is immediately to the south. This district has produced mercury and also has been explored for uranium and lithium.

Metal concentrations in samples collected in the study area are too low to classify as identified resources. Nonmetallic identified commodities, such as building stone and sand and gravel, do not constitute identified resources in the study area as they are small, of low quality, and far from prospective markets.

APPRAISAL OF IDENTIFIED RESOURCES OF THE TWELVE MILE CREEK WILDERNESS STUDY AREA

By Steven W. Schmauch
U.S. Bureau of Mines

There are no identified resources in the Twelve Mile Creek Wilderness Study Area (Schmauch, 1987). No mineralized fracture systems, visibly altered rocks, or intensely silicified areas, like those in the Opalite mining district, were seen during traverses across the study area, and no significant accumulations of unwelded ash-flow tuffs or tuffaceous sedimentary rocks were observed.

There are no mining claims in or adjacent to the study area, and there is no recorded past or current mining activity. Analyses of alluvial samples collected in the main drainages indicate slightly anomalous concentrations of molybdenum, lead, and arsenic in the southeastern part of the study area but not in sufficient concentrations to identify resources.

APPRAISAL OF IDENTIFIED RESOURCES OF THE WILLOW CREEK WILDERNESS STUDY AREA

By Thomas J. Peters
U.S. Bureau of Mines

Mining and Mineral Exploration History

A search of BLM and Harney and Malheur County records uncovered no evidence of mining claim locations or of leases for minerals, gas, or oil. No evidence of mining or prospecting was seen during traverses of the study area. Most mining and prospecting in the region has been confined to the McDermitt caldera complex, southeast of the study area, which contains several important mercury, uranium, and lithium deposits (Rytuba and Glanzman, 1979). The Whitehorse caldera, northwest of the study area, hosts diatomite deposits and an epithermal uranium, mercury, and precious-metal prospect at Flagstaff Butte, 8 mi west-northwest of the study area.

There is no history of mining in the Willow Creek study area. Gray and others (1983, appendix B) reported that more than half of the 30 stream-sediment samples they collected from the study area contain anomalous beryllium, mercury, lead, tin, and uranium. Bukofski and others (1984, appendix K) collected 30 panned-concentrate samples from the study area and reported anomalous copper, fluorine, molybdenum, silver, tin, and tungsten. A draft environmental impact statement (U.S. Bureau of Land Management, 1985, p. 283) indicates moderate or low favorability for beryllium, silver, mercury, and geothermal resources, as well as possible gold, lithium, and pumice resources.

Methods of Investigation

The USBM collected 57 rock and 40 alluvial samples to evaluate the possibility of identified resources in areas where Gray and others (1983) or Bukofski and others (1984) indicated geochemical anomalies and in areas where the U.S. Bureau of Land Management (1985) suggested mineral resources. The rock samples were collected from volcanic units, especially from the porous tuff of Trout Creek Mountains, which is capped by the impermeable tuff of Long Ridge and was considered a prospective host rock for submicroscopic beryllium (bertrandite) mineralization. All samples were tested for radioactivity and fluorescence. Rock samples were dried, pulverized, and analyzed for 27 elements by neutron-activation analysis. Alluvial samples were concentrated on a Wilfley table to extract gold and other heavy minerals, and a split of each concentrate was analyzed for 18 elements by inductively coupled plasma methods.

Results of Investigation

There are no identified mineral resources in the Willow Creek Wilderness Study Area. Although concentrations were too low to delineate identified resources, sampling by the USBM detected slightly elevated concentrations of several elements at two sites. One sample, from an area of hematitic alteration along a poorly exposed fault near the northeast corner of the study area (fig. 5, No. 1), contains twice the expected normal (background) concentrations of arsenic, antimony, and cesium. Arsenic and antimony are common indicators of gold mineralization; however, no significant levels of gold were detected. The other sample, taken from a silicified zone between two faults in the southern part of the study area (fig. 5, No. 2) contains slightly more than twice the background concentrations of uranium, cesium, and the rare-earth elements lanthanum, scandium, thorium, and ytterbium. Rare-earth elements are currently of interest for high-technology applications; however, sample concentrations are too low to be of economic interest. Cesium, found at both sites, is commonly an indicator for beryllium mineralization; however, beryllium at both sites did not exceed the background concentration.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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Geology

The Fifteen Mile Creek, Oregon Canyon, Twelve Mile Creek, and Willow Creek Wilderness Study Areas are in the northern part of the Basin and Range physiographic province, a region characterized by northeast-trending, uplifted ranges, and intervening basins and calderas. The four contiguous study areas are located mostly on the uplifted plateaus of the Oregon Canyon and Trout Creek Mountains (fig. 1). They are bounded by the Quinn River Valley on the east, the McDermitt caldera complex on the south, and the Whitehorse caldera on the northwest. The Oregon Canyon and Trout Creek Mountains are capped by Miocene rhyolitic ash-flow tuffs erupted from the McDermitt caldera complex and the Pueblo and Whitehorse calderas to the south, west, and northwest, respectively. Underlying the tuffs is a thick sequence of basalt, basaltic andesite, andesite, and rhyolite flows. This entire sequence dips 3° to 5° north-northwest to northwest.

The oldest rocks exposed in the study areas are porphyritic basalt flows that contain large plagioclase phenocrysts. Flows average 20 ft thick, have vesicular tops, and typically form prominent ledges. Air-fall tuffs and flow breccias are present locally. These basalt flows may be correlated with the Steens Basalt (Mankinen and others, 1987).

The tuff of Oregon Canyon overlies these flows (fig. 3). It erupted 16.1 million years ago from the Washburn caldera, the oldest in the McDermitt caldera complex. The tuff is chemically zoned from peralkaline rhyolite at the base through low-silica rhyolite in the middle to dacite at the top. The lower peralkaline part of the unit is white to bluish white, porphyritic, densely welded tuff that is granophyrically crystallized. Phenocrysts make up as much as 10 percent of the rock and consist of sanidine (5 percent), quartz (4 percent), and sodium amphibole (1 percent). The peralkaline tuff grades upward into brown, porphyritic, low-silica rhyolitic tuff that, in turn, grades into dacitic tuff near the top of the unit. This dacitic tuff is less welded and is characterized by reddish-brown pumice and ash.

A flow sequence above the tuff of Oregon Canyon (figs. 2–5) is dominated by andesite and basaltic andesite flows. These flows are locally interstratified with andesitic to basaltic tuffs and flow breccias. Rhyolite flows are found locally in the uppermost and middle parts of this volcanic sequence in the southern and eastern parts of the Oregon Canyon and Trout Creek Mountains. The basaltic andesite and andesite flows are generally aphyric, but two flows near the base of the sequence have abundant large plagioclase phenocrysts. Around the margin of the Washburn caldera (fig. 1), porphyritic rhyolite flows and breccias make up the base of these flows. They form a very thick sequence within the Washburn caldera but thin abruptly to the north.

The tuff of Trout Creek Mountains overlies the andesite and basaltic andesite flows. It erupted 15.8 million years ago from the Pueblo caldera adjacent to Steens and Pueblo Mountains about 25 mi west of the study areas. This ash-flow tuff is a single cooling unit composed of porphyritic peralkaline rhyolite with phenocrysts of potassium feldspar (26 percent), quartz (1 percent), and aenigmatite (1 to 5 percent). The basal part of the unit consists of bedded air-fall and base-surge deposits in which phenocrysts predominate over the ash components. These deposits grade upward into a basal black vitrophyre as thick as 6 ft. The remainder of the tuff is densely welded and granophyrically crystallized. The unit has a distinctive blue-green color, which strongly contrasts with the enclosed chatoyant potassium-feldspar phenocrysts. The tuff, which has an average thickness of about 220 ft, has local columnar jointing, and forms prominent cliffs along canyon walls.

Porphyritic rhyolite plugs and dikes cut all units older than the tuff of Long Ridge. These intrusions, near the eastern margin of the Oregon Canyon study area (fig. 3), contain phenocrysts of quartz (5.5 percent), sanidine (5.5 percent), biotite (1 percent), and pyroxene (less than 1 percent) in a cryptocrystalline groundmass of quartz and feldspar.

Overlying the tuff of Trout Creek Mountains is the tuff of Long Ridge, which caps the plateaus within the study areas (figs. 2–5) and extends farther south, west, and north. This ash-flow tuff was erupted about 15.6 million years ago from the Long Ridge caldera, the youngest in the McDermitt caldera complex. The tuff is complexly chemically zoned, ranges from peralkaline rhyolite in the lower part to low-silica rhyolite in the upper part, and has an average thickness of about 350 ft. The peralkaline rhyolite is aphyric, whereas the low-silica rhyolite is porphyritic. The base of the unit is a brick-red unwelded tuff that grades upward into a black basal vitrophyre as thick as 6 ft. Above the vitrophyre is the aphyric part of the tuff, which is greenish gray, densely welded, and granophyrically crystallized. Brown porphyritic tuff is interstratified with the middle and upper parts of the aphyric tuff and makes up the upper part of the unit. Nonwelded black pumiceous tuff is present locally in the uppermost part of the unit.

The youngest ash-flow tuff is the tuff of Whitehorse Creek, which was erupted from the Whitehorse caldera about 15 million years ago and is present only in the northwest tip of the Fifteen Mile Creek study area (fig. 2). It is a peralkaline rhyolite tuff that consists of two main cooling units separated by bedded air-fall tuffs and capped by welded tuff. The lower unit is nonwelded, light gray, and pumiceous. The lower part of the upper unit is a nonwelded gray pumiceous tuff that grades upward into a dark-gray to black tuff. Above the upper cooling unit is welded tuff that contains sanidine phenocrysts (as much as 5 percent). This tuff of Whitehorse Creek forms prominent red-brown cliffs along canyon walls and has an average thickness of about 125 ft.

Quaternary alluvium is present in canyons and along the margins of the mountain ranges. The alluvium consists of coarse, poorly sorted, locally derived material.

The buried margin of the Washburn caldera transects the southeastern part of the Oregon Canyon study area. The caldera boundary is defined by the lack of outcrops of the tuff of Oregon Canyon, which has been displaced downward within the caldera and covered by caldera-fill rhyolite flows and flow breccias. Part of this caldera margin was reactivated along a northeast-trending fault during collapse of the younger Long Ridge caldera. Rhyolite dikes having similar trends have been emplaced along the projected caldera margin but are too small to map at this scale.

The north wall of the Long Ridge caldera is well developed as a topographic feature within the southern part of the Oregon Canyon study area. The structural margin of the caldera lies south of the study area, but several arcuate normal faults subparallel to the main zone of structural collapse transect the southwestern part of the study area. These faults have displacements as large as 1,500 ft, but usually 840 ft or less, which are generally down toward the caldera. Near the border of the Long Ridge caldera, volcanic units dip as much as 15° inward toward the caldera.

One arcuate normal fault that has a displacement of about 1,500 ft, adjacent to and within the southernmost part of the Oregon Canyon study area, has accommodated much of the collapse of the Long Ridge caldera. South of this fault, the volcanic units dip as much as 30° inward toward the caldera. Hydrothermal alteration occurred along the fault zone and spread out laterally into the volcanic rocks north and south of the zone. The alteration formed from the same hydrothermal system that formed the Bretz mercury and Aurora uranium deposits 1.5 mi to the southeast (fig. 1).

In the southwestern part of the Oregon Canyon study area, six arcuate normal faults subparallel to the structural margin of the Long Ridge caldera displace the volcanic sequence downward to the south about 900 ft. All the faults except one displace fault blocks down toward the caldera. One fault displaces rocks downward away from the caldera, creating a graben having a maximum width of 0.3 mi and a strike length of 2.5 mi. Hydrothermal alteration occurred along each of these faults but was most intense along those nearest the main structural margin of the Long Ridge caldera. Alteration extended laterally into volcanic rocks adjacent to the faults.

A few normal faults that strike northeast, north, and north-northwest and have displacements as large as 320 ft transect the study areas. They displace all of the stratigraphic units and are probably related to Basin-and-Range extension.

Geochemistry

A reconnaissance geochemical survey was conducted in the Fifteen Mile Creek, Oregon Canyon, Twelve Mile Creek, and Willow Creek Wilderness Study Areas in the summer of 1986. Samples of stream sediments from 191 sites, and heavy-mineral concentrates derived from them, and 16 rock samples were analyzed for this study. Stream sediments represent a composite of rock and soil eroded upstream from the sample site. Heavy-mineral concentrates represent the heavy minerals present in rocks exposed in the drainage basin and permit the determination of some elements that are not easily detected in stream sediments. These concentrates may include minerals related to any mineralization that might have occurred in the area of the drainage basin.

The stream-sediment samples were collected from active alluvium in the stream channels. Each one is a composite from several localities along a channel length of approximately 50 ft and was sieved through an 80-mesh screen and pulverized to a fine powder for analysis. Heavy-mineral-concentrate samples were sieved through a 10-mesh screen and then panned to remove most of the quartz, feldspar, clay-sized material, and organic matter. These raw concentrate samples were further concentrated by using a heavy liquid and a magnetic separator to produce nonmagnetic heavy-mineral-concentrate samples (hereafter called concentrates). The concentrates were ground to a fine powder for analysis.

Rocks were collected from mineralized and unmineralized outcrops and from stream float. Samples that appeared fresh and unaltered were collected to provide information about geochemical background levels. Altered or mineralized samples were collected to determine the suite of elements associated with alteration or mineralization. The rocks were crushed and pulverized to a fine powder for analysis.

The concentrate, stream-sediment, and rock samples were analyzed for 31 elements by direct-current arc semiquatitative emission spectrography (Grimes and Marranzino, 1968; Crock and others, 1987). The rocks and stream sediments were also analyzed for the following elements: arsenic, bismuth, cadmium, antimony, and zinc by inductively coupled plasma emission spectrography (Crock and others, 1987); gold by atomic absorption (Thompson and others, 1968); and mercury by atomic absorption (Koirtyohann and Khalil, 1976). The anomalous levels for each element are defined as at least twice the average concentrations of the element in the rock types found in the study areas. Analytical data and a description of the sampling and analytical techniques were provided by J.L. Jones (written commun., 1987).

Some of the concentrates contain anomalous levels of silver (2 to 150 parts per million, or ppm), bismuth (20 to greater than 2,000 ppm), antimony (200 to 2,000 ppm), lead (1,500 to 20,000 ppm), and tin (2,000 ppm and greater). The silver, bismuth, and antimony anomaly patterns suggest that a broad zone of epithermally mineralized rock crosses the southern part of the study areas. Anomalous amounts of tin (2,000 ppm and greater) are present across the southeastern part of the Oregon Canyon study area and along the boundary between the Fifteen Mile Creek and Willow Creek study areas. There are no corresponding anomalies in the stream sediments. Low-grade mineralization probably occurred during or shortly after extrusion of the volcanic rocks.

The stream-sediment data indicate several anomalous zones. Analytical results indicate that the southeastern part of the combined study areas has anomalous bismuth (2 to 3 ppm), arsenic (10 to 12 ppm), and mercury (0.15 to 0.3 ppm), that the southwestern part has anomalous bismuth (2 to 7 ppm), and that the central to west-central part has anomalous arsenic (10 to 17 ppm), molybdenum (5 to 7 ppm), and zinc (200 to 300 ppm). In the southeast anomalous zone, no sites contain both anomalous bismuth and anomalous arsenic. This area is at and near the ring fracture zone of the Long Ridge caldera where the rocks are both tuffs and flows (figs. 2–5). The southwest anomalous zone is underlain primarily by basaltic andesite and andesite flows (figs. 2, 5). A central to west-central anomalous zone has eight sites having both anomalous molybdenum and arsenic. Rocks in this zone are welded ash-flow tuff and andesite, basaltic andesite, and rhyolite flows (figs. 2, 3).

Of the 16 rock samples collected, only 4 have anomalies for a single element. One sample from the southeast zone has 0.38 ppm mercury, two from the central area have 2,000 ppm barium, and one from the central area has 200 ppm copper.

Most of the anomalies described above are single-element, low-level anomalies and are difficult to ascribe to specific mineral deposit types or ore-forming processes.

Geophysics

Geophysical evaluation of the mineral resources of the Fifteen Mile Creek, Oregon Canyon, Twelve Mile Creek, and Willow Creek Wilderness Study Areas is based on interpretations of aerial gamma-ray, gravity, aeromagnetic, and remote-sensing surveys.

Radiometric data were compiled by Geodata International, Inc., (1980a, b) for the National Uranium Resource Evaluation (NURE) program of the U.S. Department of Energy. The coverage consists of 11 east-west flightlines spaced at 3-mi intervals and 2 north-south flightlines. Flight altitudes ranged from 200 to 700 ft above the ground. Recordings were made of gamma-ray flux from radioactive isotopes of uranium, thorium, and potassium. Additional radiometric data (nine east-west lines) were collected near the south edge of the Fifteen Mile Creek and Oregon Canyon study areas at a spacing of 0.33 mi and a flight altitude of 400 to 600 ft above the ground (U.S. Geological Survey, 1982). Radiometric profiles in the region show abrupt changes of radioactive count rates over contacts between the principal rock units. Count rates generally were low over andesite and basalt, low to moderate over sedimentary rocks, and moderate to high over rhyolite. Although a radiometric high exceeding 10 ppm equivalent uranium occurs 1 mi southwest of the southeast corner of the Oregon Canyon study area, no intense anomalies indicating high concentrations of thorium or uranium were recorded along flightlines within the study areas.

High concentrations of radioelements in the study areas are not precluded, however, because, assuming a 45-degree cone of detectability at 400 ft, the flightline spacing of 3 mi only samples radioactivity for about 5 percent of the ground surface.

The U.S. Geological Survey established 114 gravity stations in and within 3 mi of the borders of the study areas in 1986 (Plouff, 1987). These data supplement that collected previously from a set of stations located mostly south of the study areas (Plouff, 1977). A gravity map prepared from these data shows a complex pattern of anomalies (fig. 6). The most conspicuous anomaly is a north-trending gravity low, having an amplitude of about 8 milligals (mGal) and extending about 8 by 20 mi, which is centered along the border between the Fifteen Mile Creek and Oregon Canyon study areas. A smaller but more intense gravity low, having an amplitude of about 11 mGal, and extending about 6 by 8 mi, is centered about 3 mi northwest of the Willow Creek study area. This gravity low reflects the contrast in densities between tuffaceous sedimentary rocks that fill the Whitehorse caldera (Rytuba and McKee, 1984) and the surrounding denser volcanic and basement rocks. Gravity-anomaly values increase northwestward by about 25 mGal in 8 mi, away from the conspicuous gravity low and through the Twelve Mile Creek area. This gravity gradient seems to be part of a fairly continuous band, having a gravity relief of at least 10 mGal, which bends and continues southeastward and southward for about 50 mi along the east and south edges of the McDermitt caldera complex (Rytuba, 1976). Plouff (1985) suggested that this and similar gravity gradients may overlie edges of underlying Cenozoic batholiths whose upper, silicic parts have lower densities than surrounding basement rocks.

A conspicuous gravity high that extends southward for about 20 mi covers most of the Willow Creek study area (fig. 6). The south edge of the gravity high overlies extensive outcrops of pre-Cenozoic plutonic rocks (Stewart and Carlson, 1978), and, therefore, the gravity high probably reflects a wedge of pre-Cenozoic basement rocks that is concealed at shallow depth beneath less-dense Cenozoic rocks that surround it. A gravity high that extends about 5 mi into the southeast corner of the Oregon Canyon study area seems to reflect the northern end of a wall of older rocks that extends for about 35 mi along the arcuate east edge of the central part of the McDermitt caldera complex. A gravity low extending southeastward then southward outside the east edge of the Oregon Canyon study area joins a major gravity low in Quinn River Valley, which Rytuba and McKee (1984) interpreted as a reflection of an underlying caldera.

A regional aeromagnetic survey was flown over the study area at a constant barometric elevation of 9,000 ft above sea level and with an east-west flightline spacing of 2 mi (U.S. Geological Survey, 1972). An intense, north-trending magnetic high overlies normally magnetized andesite flows in the southwestern part of the Willow Creek study area. Another intense magnetic high, centered near the southwest corner of the Fifteen Mile Creek study area, mostly overlies rhyolitic ash-flow tuffs, which have low magnetization elsewhere in the study areas.

A magnetic low that closely matches the shape and location of the gravity low over the Whitehorse caldera west of the study areas indicates that the intracaldera sedimentary rocks are nonmagnetic compared to surrounding volcanic rocks. A magnetic low also superimposes the gravity low east of the Oregon Canyon study area. A magnetic low similarly reflects possible sedimentary rocks beneath the gravity low along the boundary between the Fifteen Mile Creek and Oregon Canyon study areas. However, the deepest part of the magnetic low, which occurs over the southern part of the gravity low, indicates that the sedimentary rocks within, or rocks beneath, the northern part of the magnetic low apparently have weak to moderate magnetization. Alternatively, the southern part of the magnetic low may overlie reversely magnetized volcanic rocks or may incorporate reversely magnetized tuff. Several intense magnetic lows south and southwest of the study areas overlie reversely magnetized flows of Steens Basalt (Mankinen and others, 1987).

Photogeologic interpretations of linear features on 1:800,000-scale Landsat multispectral scanner images that cover southeastern Oregon were used to prepare trend-concentration maps that show two prominent linear trends in the study areas. A large region centered near the wilderness study areas has linear features that trend between about N. 35° W. and N. 15° E., which most likely reflect trends of Basin-and-Range faulting. A second, prominent, west-to-northwest set of linear features trends N. 45° to 95° W. and includes some of the faults related to caldera structures.

General Discussion of Mineral and Energy Resources

Mercury, Uranium, and Lithium

Mercury, uranium, and lithium deposits of Miocene age are associated with hydrothermal activity related to the McDermitt caldera complex. These deposits are found mostly within caldera-fill areas that do not extend in the study areas, but they may also be present in and near structures along the caldera rim. Such structures are present in the southern part of the Oregon Canyon study area. Mercury deposits occur as veins in volcanic rocks and in opalized (silicified) lake-bed sediments in the McDermitt caldera complex directly south of the study areas (Rytuba and Glanzman, 1979). The main ore minerals, cinnabar

(HgS) and corderoite ($Hg_3S_2Cl_2$), in the volcanic rocks at the Cordero mine (about 10 mi southeast of the Oregon Canyon study area) are closely associated with ring fractures of the calderas. At the McDermitt (about 10 mi southeast of the Oregon Canyon Study area), Opalite, and Bretz mines, locations of ore minerals are controlled by favorable beds in sediments. In the mineralized areas, rhyolitic rocks have been silicified and basaltic rocks have

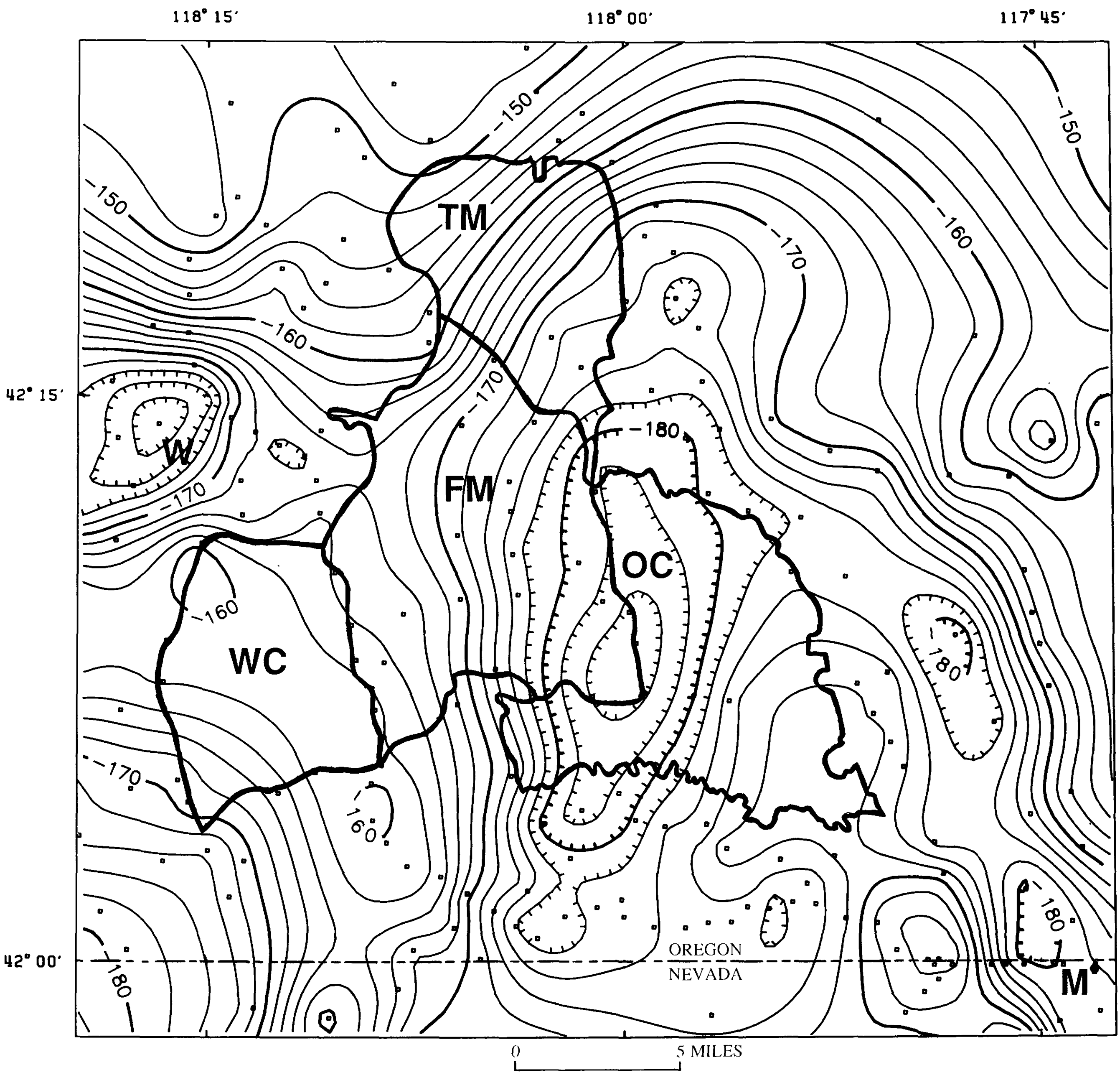

Figure 6. Bouguer gravity map for area including Fifteen Mile Creek (FM), Oregon Canyon (OC), Twelve Mile Creek (TM), and Willow Creek (WC) Wilderness Study Areas, Malheur and Harney Counties, Oregon; bold lines indicate approximate boundaries of study areas. Contour interval 2 milligals; hachures indicate closed gravity lows. Squares indicate locations of gravity stations; W, gravity low associated with Whitehorse caldera; M, McDermitt, Nev.

been argillized. Unaltered rhyolites and caldera-fill sediments contain high concentrations of mercury (0.25–0.65 ppm) for several miles from the mercury deposits and, thus, may also have been affected by the mineralization. Mercury accumulations in the sedimentary rocks within the calderas are accompanied by widespread zeolite minerals and by local potassium feldspar and other silicate minerals near the ore deposits. The zeolites, however, may be diagenetic (Wallace and Roper, 1981). These sedimentary rocks do not extend into the study areas.

Some of the high concentrations of uranium occur in mercury deposits, but others are in rhyolitic domes emplaced along ring fractures and intrusions along the western margins of the calderas (Rytuba and Glanzman, 1979). Similar rhyolite domes occur along the north margins of the calderas (Rytuba and Glanzman, 1979) adjacent to and within the Oregon Canyon and near the Fifteen Mile Creek study areas. Some uranium concentrations also occur along flow-boundary zones (Wallace and Roper, 1981). At the Aurora deposit about 1 mi south of the Oregon Canyon study area, uraninite and coffinite are commonly localized in the upper parts of altered vesicular flows and in breccia layers, primarily within volcanic rocks of intermediate composition (Roper and Wallace, 1981). Rocks adjacent to the uranium concentrations have been altered to clay minerals, zeolites, and pyrite. The uranium minerals may have been derived from hydrothermal fluids genetically related to the host volcanic rocks, and mineralization in the adjacent sediments may be syngenetic at least in part (Roper and Wallace, 1981). Background uranium concentrations in unaltered volcanic rocks are as high as 20 ppm (Rytuba and Glanzman, 1979).

Both the uranium and mercury mineralization may be related to the same hydrothermal system, with the mercury concentrating near the surface and the uranium concentrating deeper or with the uranium forming at the last stages of hydrothermal activity (Rytuba and Glanzman, 1979; Roper and Wallace, 1981). Geochemically anomalous arsenic, molybdenum, and antimony are also present in the mercury- and uranium-enriched areas south of the study areas.

Lithium concentrations in the clay mineral hectorite are present in tuffaceous sediments altered to zeolites and potassium feldspar in altered zones within the McDermitt caldera complex (Rytuba and Glanzman, 1979). The largest lithium concentrations are in altered zones near the north and west margins of the Long Ridge caldera. These altered zones extend within 5 mi south of the study areas, but they do not continue into them; therefore, the potential for lithium is not discussed in the sections below. Hectorite is not currently a source of extractable lithium (Ferrell, 1985, p. 462, 463). Both anomalous lithium and uranium concentrations are less widespread than anomalous mercury.

Miocene mercury and uranium mineralization of hydrothermal origin also occurred on the east side of the Steens and Pueblo Mountains about 30 mi northwest of the study areas (Roback and others, 1987; Minor and others, 1987; Williams and Compton, 1953). These deposits are in silicified and argillized rocks locally enclosed in a halo of limonitic and calcitic clays. The mercury, which occurs in veins and breccia bodies, is commonly accompanied by iron and copper sulfides and barite. Only some of these deposits are related to a caldera structure.

Epithermal Vein Deposits

Two mining districts near the study areas have precious-metal quartz veins and associated disseminated ore minerals that are thought to be genetically related to subsidence features similar to calderas. These are the National mining district in the Santa Rosa Mountains, about 35 mi southeast of the study areas (Vikre, 1985), and the Silver City and DeLamar mining districts in Idaho, about 90 mi northeast of the study areas (Piper and Laney, 1926; Pansze, 1975; Halsor, 1983). Quartz veins host gold- and silver-bearing sulfide and sulfosalt minerals in these districts, and ore mineral are also disseminated in the country rock in the Silver City district. Silicic alteration has characteristically occurred in these deposits, but in some places adularia, sericite, clay minerals, chlorite, and other minerals are also present. Precious-metal quartz veins in the National district occur in a thick volcanic and intrusive sequence along the west side of a shallow structural basin that resembles a partly collapsed caldera (Vikre, 1985). Ore occurs in rhyolitic rocks of the sequence. In addition to gold and silver in these veins, mercury, antimony, copper, lead, zinc, and arsenic are present in the upper part of the system. Veins and disseminated ore in the DeLamar deposit occur in a ring dome complex that has some features of a caldera system, and structural control localizes the ore deposits (Halsor, 1983). Rhyolitic lava flows and exogenous domes are the main host rocks in a bimodal suite of volcanic rocks. Supergene enrichment may have been important in the district (Piper and Laney, 1926). Small concentrations of antimony, arsenic, copper, lead, zinc, and selenium are also present. These deposits all formed about 15 to 16 million years ago in middle Miocene. This is near the time of volcanic and hydrothermal activity in the McDermitt caldera complex (Rytuba and McKee, 1984).

Although no epithermal gold and silver ore bodies have been discovered in the McDermitt caldera complex, the geologic environment resembles those of mining districts described above. In the southwestern part of the Trout Creek Mountains about 15 mi southwest of the study areas, anomalous silver concentrations as high as 16 ppm (S.A. Minor, oral commun., 1987), in rock samples from the upper part of the tuff of Oregon Canyon, suggest the possible presence of epithermal veins. Geochemical data from the Fifteen Mile Creek, Oregon Canyon, Twelve Mile Creek, and Willow Creek study areas also suggest that a broad region centered in the Fifteen Mile Creek study area may have been permeated by hydrothermal fluids enriched in antimony, bismuth, mercury, and silver and possibly in molybdenum and zinc. However, mineralized and altered areas that may have formed by such a hydrothermal system have not been identified, so the nature and extent of any such mineralization is unknown.

Rare-earth Elements and Zirconium

Base-surge deposits near the base of the tuff of Trout Creek Mountains are locally enriched in phenocrysts. Concentrations of phenocrysts such as aenigmatite, a sodium-iron-titanium silicate that is rich in rare-earth elements and zirconium (Conrad, 1984), may locally be high enough to constitute a resource for light rare-earth elements and zirconium.

Tin

Geochemical anomalies for tin in the southeastern and southwestern parts of the study areas may possibly have been derived from basaltic flows in the areas. Similar tin anomalies have been found in basalt in the Sheephead Mountains, Oreg. (D.R. Sherrod, oral commun., 1987), and tin from the four study areas may have had a similar origin. A deposit model for this type of anomaly has not yet been developed.

Industrial Minerals

Zeolite minerals are present in lakebed sedimentary rocks of the McDermitt caldera complex, either as hydrothermal alteration products associated with mercury mineralization (Glanzman and Rytuba, 1979) or as a result of diagenesis of the sediments (Wallace and Roper, 1981). The zeolite minerals include clinoptilolite, mordenite, erionite, and analcime (Glanzman and Rytuba, 1979). Zeolites also occur in caldera-fill rocks in the Whitehorse caldera directly north of the Willow Creek study area (Rytuba and others, 1981). These sedimentary environments do not extend into the study areas. Zeolite minerals commonly also occur in altered tuffaceous volcanic and sedimentary rocks; however, they were not seen in the tuffs in these study areas and, if present, are not likely to be abundant.

Pumice and perlite are commonly found in young volcanic terranes. Small perlite resources have been identified in Tertiary volcanic rocks in the Steens Mountain area about 30 mi west of the study areas (Minor and others, 1987), where perlite is found in the glassy margin of a rhyolite dome. Pumice fragments have been found in the nonwelded parts of the tuff of Long Ridge north of the Twelve Mile Creek study area (Peterson and Tegtmeyer, 1987), but typically they are scattered throughout the ash matrix. Minor nonwelded tuff may extend into the extreme northern part of the study area, although it is unlikely that any large accumulations would be present. Pumice is also present in limited exposures of the lower part of the tuff of Whitehorse Creek in the Fifteen Mile Creek study area. Pumiceous nonwelded tuff was not seen in the other study areas.

Diatomite constitutes about the upper 100 ft of caldera-fill deposits from the Whitehorse caldera in a drill core taken from about 3 mi northwest of the Willow Creek study area (Rytuba and others, 1981). The diatomite contains interbedded volcanic ash and clay layers. Below the diatomite layer are unaltered tuffaceous sedimentary rocks and, lower down, altered beds that contain zeolites and potassium feldspar. Diatomite has also been reported from sedimentary rocks of the McDermitt caldera complex (Rytuba and Glanzman, 1979). The northwest corner of the Willow Creek study area is close to exposures of caldera-fill sediments that contain diatomite but is geologically different, so resources of this type are not expected in the study area.

Rocks suitable for use as building stone and crushed aggregate are readily available in all of the study areas, but there is no local market for large quantities of these commodities. Building stone for local use is plentiful outside the study areas. The tuff of Trout Creek Mountains is locally attractive enough to warrant transportation to more distant markets for use as dimension stone.

Sand and gravel in the creeks are not considered to be resources in these study areas, even where abundant enough to map, because similar material is available closer to markets.

Geothermal Energy

Warm-water springs and wells are found at scattered localities in southeastern Oregon. The Alvord Known Geothermal Resource Area lies about 25 mi northwest of the study areas, and smaller localities with warm-water wells are even closer (Oregon Department of Geology and Mineral Industries, 1982). Seven wells and springs about 5 mi northwest of the Willow Creek study area have temperatures ranging from 68 to 127 °F. Five wells in two areas 5 mi northeast of the Twelve Mile Creek study area have temperatures ranging from 70 to 111 °F. Two warm-water springs, one about 5 mi east and the other 5 mi south of the Oregon Canyon study area, have temperatures of 126 and 97 °F, respectively (Oregon Department of Geology and Mineral Industries, 1982). Waters in these temperature ranges could be used for local space heating but are unsuitable for power generation because of their low temperature and the small size of the springs. Although these warm-water wells and springs are nearby, they all occur in valleys and calderas. Because the study areas are within mountain ranges, they have only low potential for geothermal energy resources.

Oil and Gas

The resource potential for oil and gas for most of southeastern Oregon is low (Fouch, 1983). However, some areas may be underlain by nonmarine sedimentary rocks, and some of these may contain organic remains. If such rocks are present, heating or bacterial action could have converted any organic remains into oil or gas. The depth and structure of any such rocks below these study areas is not known.

Mineral and Energy Resources of the Fifteen Mile Creek Wilderness Study Area

There is low potential for mercury and uranium resources, certainty level C, in the southernmost part of the study area near the outer margin of the McDermitt caldera complex (fig 2). Most of the southern two-thirds of the area has low potential, certainty level B, for resources of antimony, bismuth, mercury, silver, molybdenum, and zinc in epithermal vein deposits, based primarily on geochemical information. The southwest corner of the area has low potential, certainty level B, for tin resources of unknown origin. The northwest tip of the study area, underlain by the tuff of Whitehorse Creek, may have scattered pumice and is therefore assigned low potential, certainty level B, for pumice resources. The entire study area has low potential for zeolite resources, certainty level B. The geothermal energy resource potential of the study area is low, certainty level C. The study area has low potential for oil and gas resources, certainty level C. Locally, parts of the tuff of Trout Creek Mountains have low potential for decorative building stone resources, certainty level B, although transportation to distant markets would be required. The tuff of Trout Creek Mountains also has a low mineral resource potential, certainty level B, for rare-earth elements and zirconium contained in phenocrysts. There is no potential for sand and gravel resources, certainty level D, beyond what is currently mapped.

Mineral and Energy Resources of the Oregon Canyon Wilderness Study Area

The study area has a moderate potential, certainty level B, and low potential, certainty level C, for both mercury and uranium deposits in the southern part of the area, respectively adjacent to and near to the ring fractures of the McDermitt caldera complex (fig. 3). The tuff of Oregon Canyon has low potential, certainty level B, for gold and silver resources in epithermal veins because of the proximity of the study area to the McDermitt caldera complex; the southern part of the study area, adjacent to the caldera complex, also has a low potential for gold and silver resources in epithermal vein deposits, certainty level B. On the basis of geochemical anomalies, the southern and northwestern parts of the area have low potential, certainty level B, for antimony, bismuth, mercury, silver, molybdenum, and zinc in epithermal deposits. Geochemical anomalies indicate that the southeastern half of the area has low potential, certainty level B, for deposits containing tin resources of unknown origin. The entire study area has low potential for zeolite resources, certainty level B, because of the presence of favorable rock types, even though zeolites have not been seen. The study area has low resource potential for geothermal energy, certainty level C, and for oil and gas resources, certainty level C. Locally, the tuff of Trout Creek Mountains has low resource potential, certainty level B, for decorative building stone, although transportation to distant markets would be required. The tuff of Trout Creek Mountains also has a low mineral resource potential, certainty level B, for rare-earth elements and zirconium contained in phenocrysts. There is no potential for sand and gravel resources, certainty level D, beyond what is currently mapped.

Mineral and Energy Resources of the Twelve Mile Creek Wilderness Study Area

The entire study area has low potential, certainty level B, for zeolite resources because favorable rocks are present, even though zeolites have not been seen (fig. 4). Scattered pumice fragments are present north of the study area in nonwelded parts of the tuff of Long Ridge, and the northernmost part of the study area, where small amounts may also be present, has low resource potential, certainty level B, for pumice. The study area has low resource potential for geothermal energy, certainty level C, and for oil and gas, certainty level C. Locally, the tuff of Trout Creek Mountains has low potential, certainty level B, for decorative building stone resources, although transportation to distant markets would be required. The tuff of Trout Creek Mountains also has a low mineral resource potential, certainty level B, for rare-earth elements and zirconium contained in phenocrysts. There is no potential for sand and gravel resources, certainty level D, beyond what is currently mapped.

Mineral and Energy Resources of the Willow Creek Wilderness Study Area

The southern part of the area has low mineral resource potential, certainty level B, for antimony, bismuth, mercury, silver, molybdenum, and zinc in epithermal deposits (fig. 5). Geochemical anomalies for tin indicate that the southeast corner of the area has low potential, certainty level B, for tin resources of an unknown type. The area has low potential for zeolite resources, certainty level B, because of the volcanic terrane. The geothermal resource potential of the study area is low, certainty level C. The study area has low potential for oil and gas resources, certainty level C. Locally, the tuff of Trout Creek Mountains has a low potential, certainty level B, for decorative building stone resources, although transportation to distant markets would be required. The tuff of Trout Creek Mountains also has a low mineral resource potential, certainty level B, for rare-earth elements and zirconium contained in phenocrysts. There is no potential for sand and gravel resources, certainty level 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	H/B HIGH POTENTIAL	H/C HIGH POTENTIAL	H/D HIGH POTENTIAL
	M/B MODERATE POTENTIAL	M/C MODERATE POTENTIAL	M/D MODERATE POTENTIAL
UNKNOWN POTENTIAL	L/B LOW POTENTIAL	L/C LOW POTENTIAL	L/D LOW POTENTIAL
			N/D NO POTENTIAL

LEVEL OF CERTAINTY →

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.

Mineral Resources of Wilderness Study Areas: Trout Creek Mountains Region, Oregon

This volume was published as separate chapters A and B

U.S. GEOLOGICAL SURVEY BULLETIN 1742

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

CONTENTS

[Letters designate the separately published chapters]

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