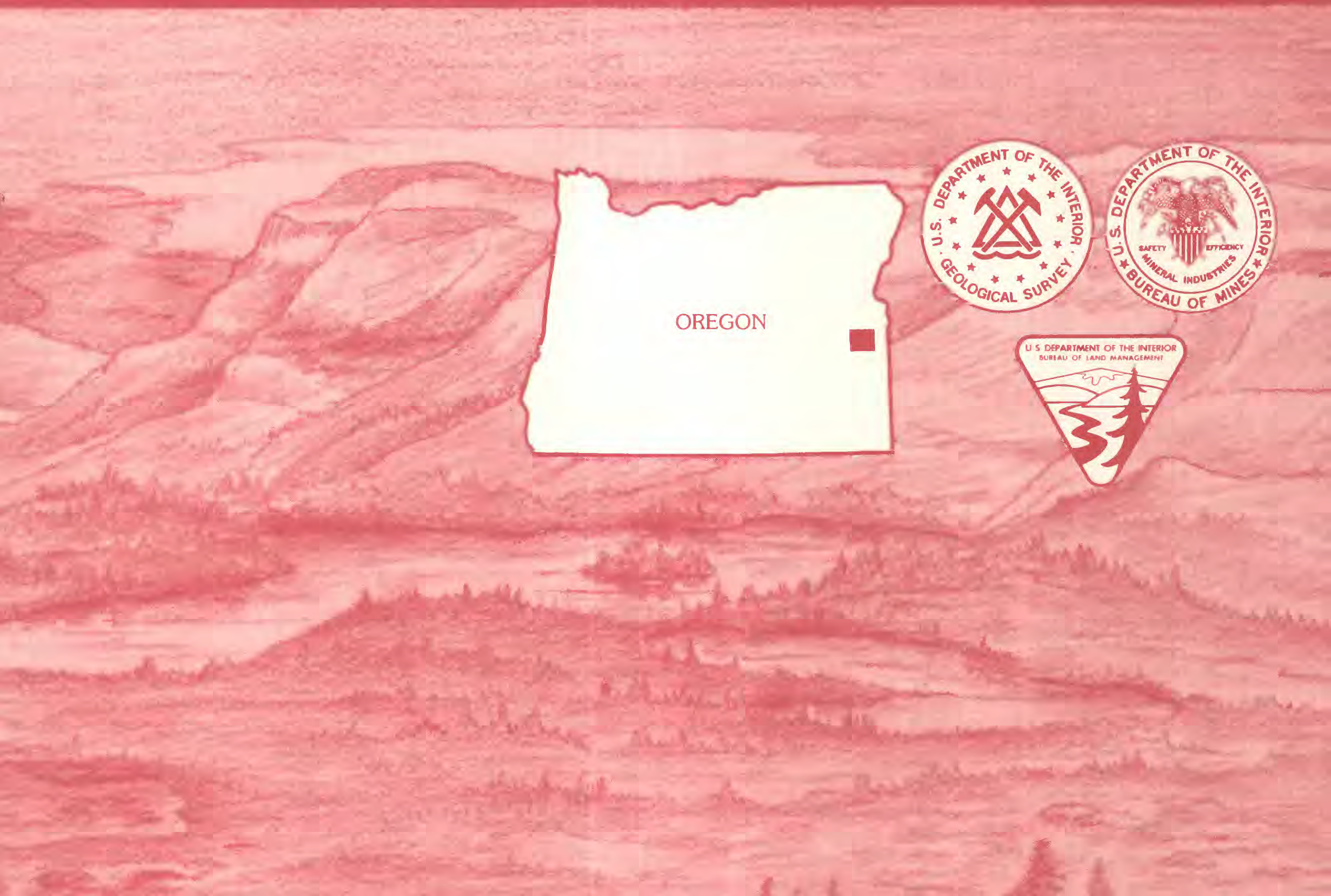
Mineral Resources of the Camp Creek and Cottonwood Creek Wilderness Study Areas, Malheur County, Oregon

U.S. GEOLOGICAL SURVEY BULLETIN 1741–C



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Chapter C

Mineral Resources of the Camp Creek and Cottonwood Creek Wilderness Study Areas, Malheur County, Oregon

By WILLIAM J. KEITH, ROBERT L. TURNER, and ANDREW GRISCOM
U.S. Geological Survey

JOHN R. BENHAM and MICHAEL S. MILLER
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1741

MINERAL RESOURCES OF WILDERNESS STUDY AREAS: EAST-CENTRAL OREGON

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, Jr., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Area

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys of 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 Camp Creek (OR-003-031) and Cottonwood Creek (OR-003-032) Wilderness Study Areas, Malheur County, Oregon.

CONTENTS

Summary C1
- Abstract C1
- Character and setting C1
- Identified resources C1
- Mineral resource potential C3

Introduction C3
- Area description C3
- Previous and present investigations C3
- Acknowledgments C5

Appraisal of identified resources C5
- Mining and exploration history C5
- Identified resources C5
  - Diatomite C5
  - Pozzolan C7
  - Sand and gravel C8
  - Stone (dimension and decorative) C8
- Mineral occurrences C8
  - Metallic minerals C8
  - Nonmetallic materials C8
- Recommendations for further work C9

Assessment of mineral resource potential C9
- Geological studies C9
- Geochemical studies C9
- Geophysical studies C10
- Mineral and energy resource potential C11

References cited C11

Appendixes
- Definition of levels of mineral resource potential and certainty of assessment C14
- Resource/reserve classification C15
- Geologic time chart C16

FIGURES

1. Index map showing location of Camp Creek and Cottonwood Creek Wilderness Study Areas, Malheur County, Oregon C2
2. Map showing mineral resource potential, generalized geology, and sample sites of Camp Creek and Cottonwood Creek Wilderness Study Areas, Malheur County, Oregon C4

TABLE

1. Identified mineral resource data for sample sites in and near the Camp Creek and Cottonwood Creek Wilderness Study Areas, Malheur County, Oregon C6

Mineral Resources of the Camp Creek and Cottonwood Creek Wilderness Study Areas, Malheur County, Oregon

By William J. Keith, Robert L. Turner, *and* Andrew Griscom
U.S. Geological Survey

John R. Benham *and* Michael S. Miller
U.S. Bureau of Mines

SUMMARY

Abstract

The Camp Creek (OR–003–031) and Cottonwood Creek (OR–003–032) Wilderness Study Areas are located in the Owyhee region of Malheur County, southeastern Oregon. At the request of the U.S. Bureau of Land Management, approximately 20,310 acres of the Camp Creek (OR–003–031) and 7,700 acres of the Cottonwood Creek (OR–003–032) Wilderness Study Areas were studied. In this report, the areas studied are referred to as "the wilderness study areas," or simply "the study areas." Geological, geochemical, geophysical, and mineral surveys were conducted by the U.S. Geological Survey and the U.S. Bureau of Mines in 1986 to assess the identified mineral resources (known) and mineral resource potential (undiscovered) of the study areas. There are no claims or mines, current or historical, in the study areas. However, two small pits of unknown origin were found on the extreme north boundary of the Camp Creek study area. Resources of diatomite, pozzolan (siliceous material used in cement), sand and gravel, and building stone were identified, and volumes were estimated. Calcite, perlite, and metal (antimony, arsenic, barium, gold, molybdenum, and tungsten) occurrences were observed in the study areas but are too small and low grade to constitute resources. In addition, these studies indicate areas of moderate mineral resource potential for epithermal-vein-type gold and (or) silver and low mineral resource potential for diatomite in the eastern part of both study areas and moderate mineral resource potential for hot-spring-type gold throughout both study areas. There is also low mineral resource potential throughout both study areas for zeolites, building stone, and pozzolan. Both study areas have low potential for high-temperature (194 to 302 °F) geothermal resources and for oil and gas resources.

Manuscript approved for publication, May 10, 1989.

Character and Setting

The Camp Creek and Cottonwood Creek Wilderness Study Areas (fig. 1) are in the rugged uplands of southeastern Oregon about 50 mi west of Boise, Idaho. The topography is typical of a deeply dissected plateau and reflects the High Lava Plains physiographic subprovince in which the study areas are located. Relief in the areas is moderate, with elevations ranging from 3,360 ft at the Stringer shearing plant to about 5,320 ft southeast of Monument Peak (fig. 2). The study areas contain a nearly horizontal sequence of lava flows, pyroclastic deposits, and associated sedimentary rocks of Miocene and Pliocene age (see geologic time chart in "Appendixes"). The rocks are cut by high-angle normal faults.

Identified Resources

Approximately 10 million tons of inferred marginal reserves of cake diatomite exist in and near the Camp Creek study area. It is estimated that inferred marginal reserves of pozzolan consist of more than 40 million tons in the inferred reserve base[1] in the Camp Creek study area and more than 10 million tons in the inferred reserve base in the Cottonwood Creek study area. Inferred marginal

[1]The in-place part of an identified resource from which inferred reserves are estimated. Quantitative estimates are based largely on knowledge of the geologic character of a deposit for which there may be no samples or measurements. The estimates are based on an assumed continuity beyond the reserve base, for which there is geologic evidence (U.S. Bureau of Mines and U.S. Geological Survey, 1980).

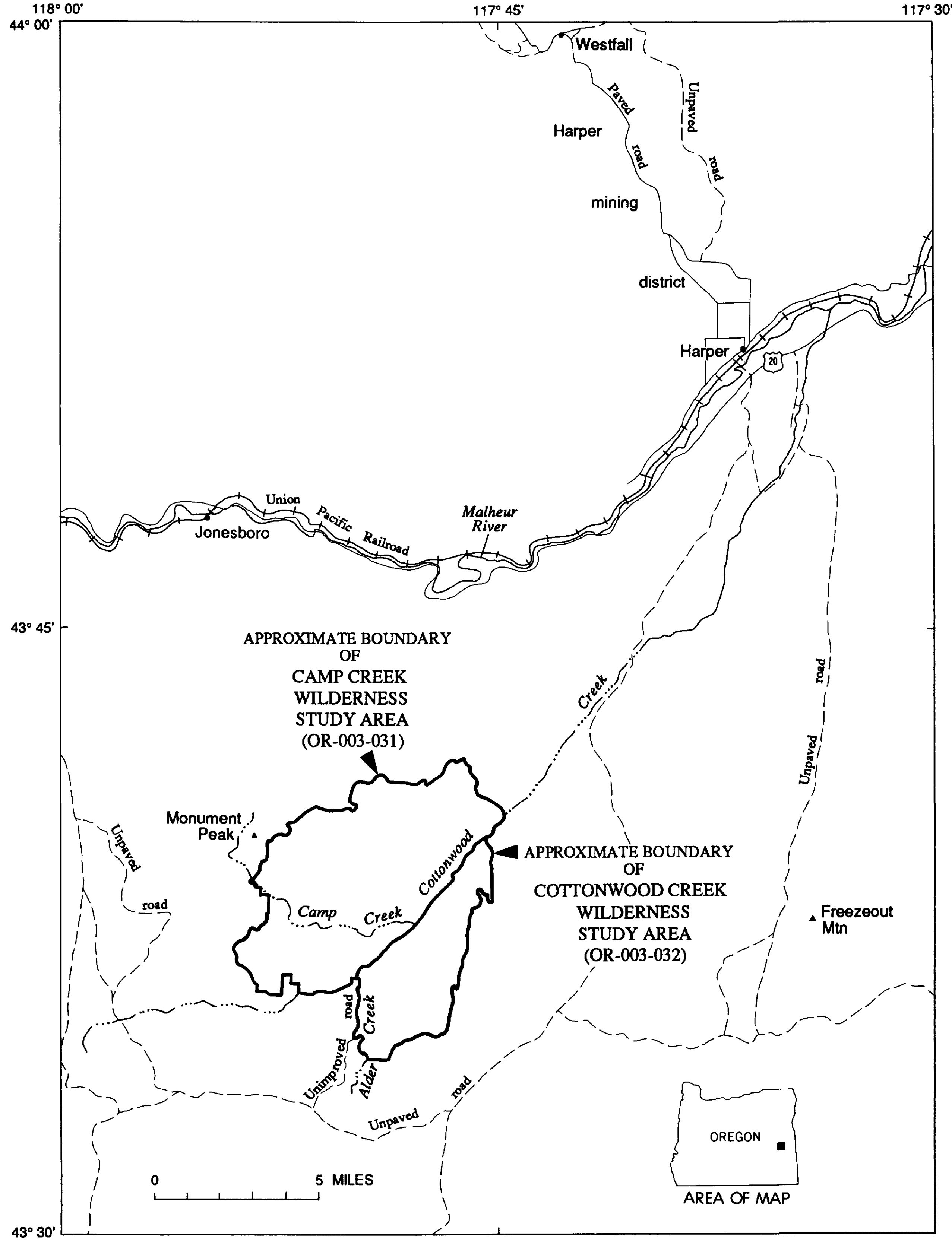


Figure 1. Index map showing location of Camp Creek and Cottonwood Creek Wilderness Study Areas, Malheur County, Oregon.

reserves for sand and gravel include a minimum of 2.5 million cubic yards in the Camp Creek study area and at least 2.5 million cubic yards in the Cottonwood Creek study area. In and adjacent to the Cottonwood Creek study area there are at least 740,000 tons of inferred marginal reserves of slab rock suitable for building stone. Perlite and calcite occurrences in the Camp Creek study area are not economic. Samples of silicified breccia from the Shearing Plant fault in the Camp Creek study area, from opalized rhyolite breccia northeast of the Gugle Ranch in the Cottonwood Creek study area, and from limonitic tuffs in the Camp Creek study area contain minor amounts of metals.

No oil and gas or geothermal leases exist in the area, and no energy resources were identified.

Mineral Resource Potential

The area along the Shearing Plant fault in both study areas has moderate mineral resource potential for a small epithermal gold and (or) silver deposit (fig. 2) as indicated by low-level geochemical anomalies, minor alteration, and the presence of quartz stringers and silicified joints associated with the fault. The mineral resource potential across both study areas is moderate for hot-spring-type gold deposits, as indicated by the opalized areas and relatively high heat flow.

Two areas in the northeastern part of the Camp Creek study area and two in the eastern part of the Cottonwood Creek study area have low potential for a viable diatomite deposit related to lacustrine sediments. Both study areas also have low mineral resource potential for zeolite deposits, as indicated by favorable host-rocks, and for building stone and pozzolan because both areas are underlain by rocks that could contain these materials.

Relatively high heat flow and the presence of high-temperature hydrothermal systems within 50 mi of the study areas suggest low potential for high-temperature (194 to 302 °F) geothermal energy resources in both study areas.

Both study areas also have low potential for oil and gas resources. Source beds that may underlie or be interstratified with older rocks exposed in this area could contain oil and gas.

INTRODUCTION

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

Area Description

At the request of the U.S. Bureau of Land Management, approximately 20,310 acres of the Camp Creek (OR–003–031) and 7,700 acres of the Cottonwood Creek (OR–003–032) Wilderness Study Areas were studied. The two study areas join along a section of Cottonwood Creek in a sparsely vegetated, plateau-type terrain in northern Malheur County, Oreg. (fig. 1). The Union Pacific Railroad and U.S. Highway 20 cross the region about 5 mi north of the study areas, which are accessible from all sides by unmaintained jeep trails. The interior is accessible only by helicopter or horseback or on foot. Elevations range from 3,360 ft at the Stringer shearing plant to about 5,320 ft southeast of Monument Peak (fig. 2).

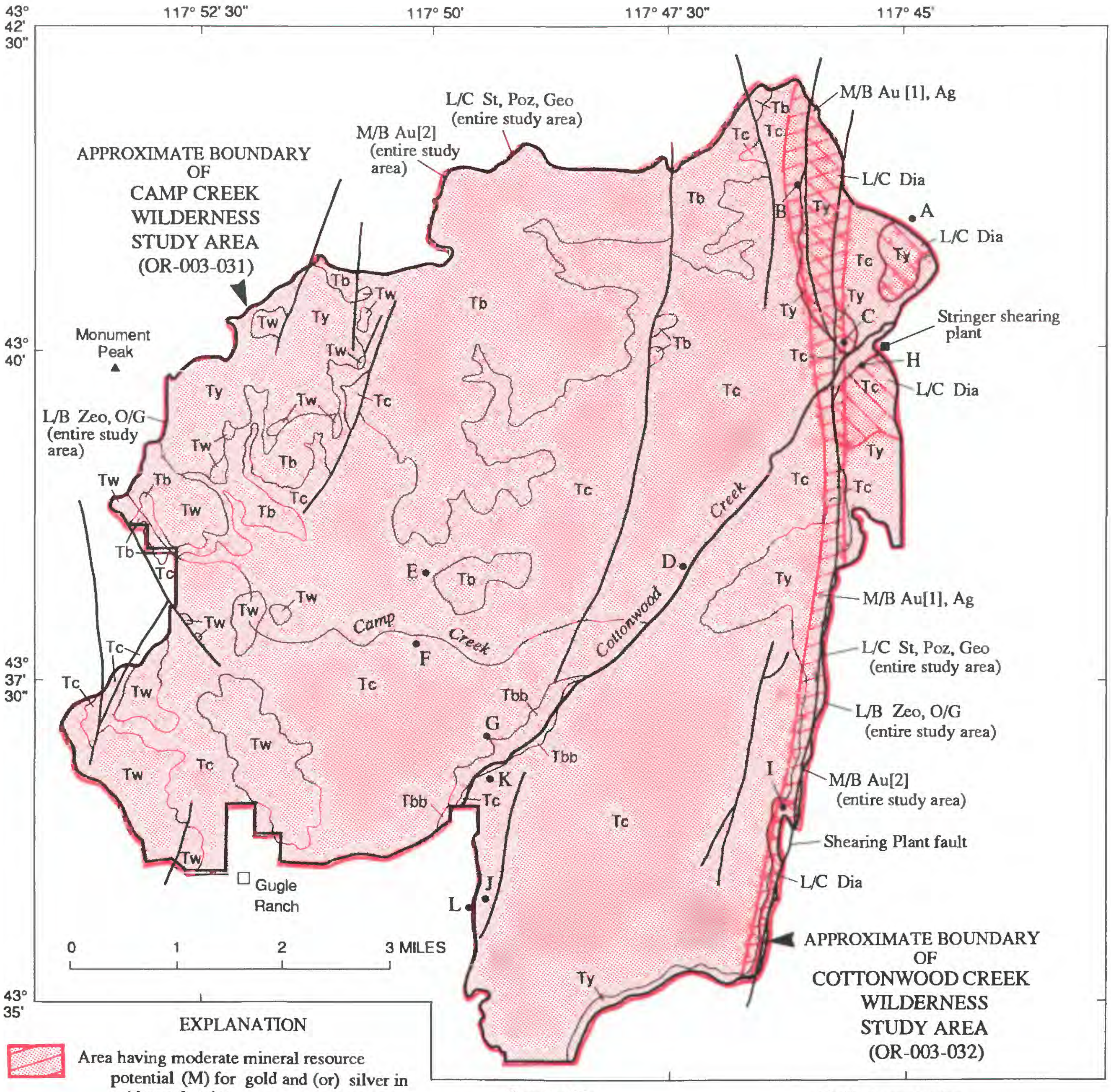
Previous and Present Investigations

The geologic map (fig. 2) is based on published and unpublished geologic maps of Hagood (1963a) and Kittleman and others (1967). Studies by Kittleman and others (1965) and Mathews and Blackburn (1983) also provided geologic data for this report.

Geochemical data were obtained from analyses of stream-sediment samples collected by the U.S. Geological Survey (Jones and others, 1988) from streams draining the study areas. Bedrock samples were also collected and analyzed as a means of obtaining background and alteration data.

Geophysical data consist of aeromagnetic surveys by the Geophysics Group at Oregon State University (Boler, 1978) and geoMetrics, Inc. (1979) as well as gravity data from a study by Lillie (1977). Aerial gamma-ray spectrometer data are also available from geoMetrics, Inc. (1979).

The U.S. Bureau of Mines studied the known prospects and claims within and adjacent to the study areas as a means of developing a model that would predict the grade and tonnage of mineral resources identified in the study



EXPLANATION

Area having moderate mineral resource potential (M) for gold and (or) silver in epithermal veins

Area having moderate mineral resource potential (M) for epithermal hot-spring gold and low mineral resource potential (L) for other commodities as noted

Area having low mineral resource potential (L) for diatomite

Levels of certainty of assessment

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

Commodities

Au	Gold
Ag	Silver
Dia	Diatomite
Geo	Geothermal energy
O/G	Oil and gas
Poz	Pozzolan
St	Building stone
Zeo	Zeolite

[ ] Types of gold deposits

1 Epithermal vein

2 Epithermal hot spring

Geologic map units

Ty	Younger volcanic and associated sedimentary rocks (Tertiary)
Tw	Wildcat Creek Welded Ash-Flow Tuff of Kittleman and others (1965) (Tertiary)
Tb	Basalt flows (Tertiary)—Upper part, Tims Peak Basalt; lower part, basalt flows and volcanic breccias
Tc	Crowley Formation of Hagood (1963a,b) (Tertiary)
Tbb	Basaltic breccia (Tertiary)—Phase of the unnamed igneous complex of Hagood (1963a)

Contact

Fault

• A Sample site—Letter refers to table 1

Figure 2. Mineral resource potential, generalized geology, and sample sites of Camp Creek and Cottonwood Creek Wilderness Study Areas, Malheur County, Oregon.

areas. During this process, they collected and analyzed 15 alluvial and 66 rock samples. Details of samples and analytical procedures are described by Benham and Miller (1988).

Acknowledgments

J. Douglas Causey of the U.S. Bureau of Mines assisted with the fieldwork in 1987. The authors express gratitude to Mr. Bill Holsheimer, Bureau of Land Management geologist of Vale, Oreg., for providing aerial-photograph coverage, maps, and logistical information. Mr. Glen Teague, owner of Teague Mineral Products in Adrian, Oreg., explained his zeolite deposit and its mining, production, and use. Mr. Andrew Visocan, mine and plant manager of Eagle-Picher Industries, Inc., in Vale, Oreg., described their diatomite deposits, mining, and production. Mr. James Canwell of the U.S. Bureau of Mines identified diatoms and determined the refractive index of volcanic glass samples.

APPRAISAL OF IDENTIFIED RESOURCES

By John R. Benham *and* Michael S. Miller
U.S. Bureau of Mines

Mining and Exploration History

There has been no exploration activity (staked claims) or mining in the Camp Creek and Cottonwood Creek Wilderness Study Areas. Two small pits of unknown age were found at the north end of the Camp Creek Wilderness Study Area. The nearest historical mining activity was at the Harper district (diatomite) about 23 mi to the north.

The Harper mining district covers more than 50 mi^2 and has diatomite resources in the lower and upper diatomite members of the Miocene Payette Formation (Moore, 1937, p. 65–71). A German physician developed a small mill in 1910 and shipped limited amounts of diatomite by stage to the railroad at Harper, Oreg.; shipments ended shortly thereafter with his death. From 1923 until 1933, Whiteurth Products Company took over mining (Moore, 1937, p. 92, 93). In 1971, the railroad was extended into the Harper district, and mining was renewed by the American Diato Company. There have been several attempts to revitalize the district; the Manville Corporation was evaluating diatomite in the Harper Basin in 1987 (Ramp, 1988, p. 42, 43).

Diatomite has been produced since 1985 by Eagle-Picher Industries at the Celatom mine north of U.S. Highway 20, about 30 mi northwest of the study areas. The processing plant is at Vale, Oreg. The diatomite occurs in the Cenozoic Juntura Formation of Bowen and others (1963) and the Drewsey Formation and is shipped to western markets for use as a filter aid (Andrew Visocan, oral commun., 1986; Brittain, 1986).

Zeolite and bentonite have been mined 34 mi east of the Cottonwood Creek study area since 1972 by Teague Mineral Products, Adrian, Oreg. Production is from one zeolite pit and three bentonite pits. Production of zeolite and bentonite from Miocene tuffaceous sedimentary rocks was 4,000 and 12,000 short tons, respectively, in 1985 and 5,000 and 14,000 short tons in 1986. Reserves are estimated to be millions of tons (Glen Teague, oral commun., 1987).

There are no oil and gas or geothermal leases or lease applications in the study areas, and industry has shown no interest in energy resources exploration in the area.

Identified Resources

Selected sample sites for U.S. Bureau of Mines studies are shown on figure 2. Resulting identified mineral resource data are summarized in table 1. All estimates are in short tons.

Diatomite

Diatomite, a mineral commodity having significant resources in and near the study areas, is an indurated accumulation of siliceous aquatic microscopic plant remains. It is used in the United States as filtering material to purify water and various food-processing and industrial fluids (67 percent), as a filler (17 percent), and in numerous other purposes (16 percent). Apparent U.S. consumption in 1987 was estimated at 532,000 short tons. Average price, f.o.b. (free on board) plant, was $203 per short ton in 1987 (Meisinger, 1988).

Thick beds of diatomite crop out at the northeast end of the Camp Creek study area, become thinner to the west, and extend south along the east side of the Cottonwood Creek study area. The diatomite is generally the coherent, friable, cake type; however at most outcrops it has been broken by landslides. One exposure of diatomite, more than 114 ft high, crops out just outside the northeast boundary of the Camp Creek study area (fig. 2, table 1, site A). Exposures within the study areas are several hundred feet across and a few feet to a few tens of feet thick. Sample descriptions and analytical results are in Benham and Miller (1988).

Diatomite reserves in and adjacent to the Camp Creek study area are considered to be marginally economic because of the low grade and the competition from established mines. Two areas in or near the Camp Creek study area were sampled. At site A, a 48-ft-thick section of diatomite having a block density of 40 pounds per cubic foot (lb/ft^3) would yield about 4.3 million tons of inferred marginal reserves of diatomite. Underlying this material is an additional 66-ft-thick section having a block density of about 36 lb/ft^3, which would yield approximately 5.3

Table 1. Identified mineral resource data for sample sites in and near the Camp Creek and Cottonwood Creek Wilderness Study Areas, Malheur County, Oregon

[*, wholly or partly outside study area. As, arsenic; Ba, barium; Eu, europium; Fe, iron; La, lanthanum; Mo, molybdenum; Rb, rubidium; Sb, antimony; Th, thorium; U, uranium; W, tungsten; Yb, ytterbium; Al_2O_3, aluminum oxide; CaO, calcium oxide; Fe_2O_3, ferric oxide; K_2O, potassium oxide; MgO, magnesium oxide; MnO, manganese oxide; Na_2O, sodium oxide; P_2O_5, phosphorus pentoxide; SiO_2, silicon dioxide; and TiO_2, titanium dioxide; ppm, parts per million; ppb, parts per billion]

Sample site (fig. 2)	Rock type	Description	Chemical and mineral resource data
		Camp Creek Wilderness Study Area	
A*	Diatomite	Tuffaceous, brown to white bedded diatomite at least 114 ft thick.	Block density is 36 to 40 lb/ft^3. *Melosira, Tetracyclus, Stephanodiscus, Nayicula,* and sponge spicules identified. A 48-ft-long sample contains 77.2 percent SiO_2, 6.8 percent Al_2O_3, 3.52 percent Fe_2O_3, 1.21 percent MgO, 1.31 percent CaO, 0.47 percent Na_2O, 0.33 percent K_2O, 0.31 percent TiO_2, less than 0.01 percent P_2O_5, 0.04 percent MnO; loss on ignition was 8.87 percent. This layer contains inferred, marginally economic reserves of 9.6 million short tons of diatomite.
B	Breccia zone	Red, brown, and gray basalt and rhyolite (?) breccia with stretched vesicles and some opal-filled vesicles. Some limonite staining and silicified fractures and chalcedony/opal-rich cement.	Twenty-two samples average 7 ppm Mo, 6 ppm As, 0.8 ppm Sb, 1,700 ppm Ba, and 11 ppm W. These concentrations are too low by a factor of about 100 to be economic.
C	Diatomite	Bedded, brown, green, and white diatomite, 50 ft thick in an area obscured by talus, slopewash, and landslides.	Block density 40 lb per ft^3. *Melosira, Analus, Cymbella, Tetracylus, Cyclotella,* and sponge spicules identified. One grab sample contains 76.67 percent SiO_2, 8.27 percent Al_2O_3, 2.16 percent Fe_2O_3, 0.88 percent MgO, 1.55 percent CaO, 0.86 percent Na_2O, 1.54 percent K_2O, 0.25 percent TiO_2, less than 0.01 percent P_2O_5, 0.02 percent MnO; loss on ignition was 8.18 percent. Marginally economic reserves of 250,000 short tons are inferred.
D	Sand and gravel.	Subangular to subrounded sand, pebbles, cobbles, and numerous boulders of basalt, andesite, and rhyolite. Extensive deposits along Camp and Cottonwood Creeks.	At least 2.5 million yds^3 of inferred marginal reserves in and near Camp Creek study area and 2.5 million yds^3 of inferred marginal reserves in and near Cottonwood Creek study area.
E	Perlite	Glassy welded tuff having slight perlite texture.	Density of expanded perlite is 27.81 lb/ft^3; standard is 3 lb/ft^3. This perlite is too low in grade to be economic.
F	Pozzolanic tuff.	Example of tuffaceous beds that underlie much of study area. Thin-bedded to massive, brown, black, gray, and white pumiceous diatomaceous tuff, nearly horizontal.	Two chip samples 20.5 and 33.0 ft long have 69.63 percent and 58.52 percent SiO_2, 14.19 percent and 15.67 percent Al_2O_3, 1.37 and 8.28 percent Fe_2O_3, 0.69 percent and 0.98 percent MgO, 1.39 percent and 2.23 percent CaO, 2.53 percent and 1.42 percent Na_2O, 5.39 percent K_2O, 0.11 and 1.02 percent TiO_2, less than 0.01 percent and 0.05 percent P_2O_5, 0.14 percent and 0.17 percent MnO; loss on ignition was 6.13 percent and 8.89 percent. Camp Creek study area is estimated to contain inferred marginal reserves of at least 40 million short tons of pozzolanic tuff in the reserve base.
G	Calcite occurrence.	Clear to milky crystals and fragments of calcite in float.	Calcite mostly milky and twinned; most crystals less than 1 in. across. Occurrence is too small and too low grade to be economic.

Table 1. Identified mineral resource data for sample sites in and near the Camp Creek and Cottonwood Creek Wilderness Study Areas, Malheur County, Oregon—Continued

Sample site (fig. 2)	Rock type	Description	Chemical and mineral resource data
		Cottonwood Creek Wilderness Study Area	
H	Diatomite	Gray to white, green to brown tuffaceous diatomite.	Five samples contain impure, clayey pumiceous diatomite with *Melosira* diatoms. Occurrence is too low grade to be economic.
I	Diatomite	Pale red, brown to gray bedded diatomite and tuff; ilmenite(?) grains as large as 1 mm. Diatomite about 10 ft thick in outcrop.	Block density is 40 lb/ft^3. The estimated 4,000 short tons of diatomite is not considered to be economic.
J	Pozzolanic tuff.	Very fine grained, white to tan tuff at least 100 ft thick.	Tuffaceous beds similar to those at site F in the Camp Creek study area. Cottonwood Creek study area is estimated to contain inferred marginal reserves of at least 10 million short tons of pozzolanic tuff in the reserve base.
K	Opalized rhyolite.	Gray, fine-grained porphyritic rhyolite with yellow to green fracture coatings of opal. Exposure at least 200 ft across.	One grab sample contains 6 ppm As, 1,500 ppm Ba, 4 ppm Eu, 1.9 percent Fe, 56 ppm La, 6 ppm Mo, 99 ppm Rb, 0.3 ppm Sb, 11 ppm Th, 5.2 ppm U, 3 ppm W, and 9 ppm Yb. These concentrations are too low by a factor of about 100 to be economic.
L*	Building stone.	Yellow, brown, and gray slabby porphyritic rhyolite in talus. Slabs are concave to wavy, 0.5 to 3.0 in. thick, 4 to 20 in. wide, and 6 to 30 in. long. Slabs are hard and have a glassy ring when struck.	Assuming a thickness of 10 ft, a width of 200 ft, and a length of 5,000 ft, inferred marginally economic reserves of more than 740,000 short tons are estimated.

million tons of inferred marginal reserves. At site C (fig. 2, table 1), the diatomite has a block density of about 40 lb/ft^3. Data indicate approximately 250,000 tons of inferred marginal reserves of diatomite at this site, although talus and slopewash limit the exposures.

Two areas of diatomaceous material in the Cottonwood Creek study area were sampled. One (fig. 2, table 1, site H) is tuffaceous and too impure to consider as a resource. Diatomite at site I is interlayered with coarse-grained pumice and has a block density of about 40 lb/ft^3. It would yield about 4,000 tons of inferred subeconomic diatomite resources.

Moore (1937, p. 113) considered diatomite having a block density of less than 30 lb/ft^3 to be excellent, that of 30 to 35 lb/ft^3 to be good, that of 35 to 40 lb/ft^3 to be fair, and that of greater than 40 lb/ft^3 to be poor. Accordingly, the quality of diatomite from the study areas is rated poor to fair. For some applications, however, denser impure diatomite may be superior to lighter diatomite. Preliminary mining costs were estimated by the methods of Benjamin and Gale (1984) using January 1988 costs. They ranged from $4.50 per ton at 500 tons per day and no stripping to $21 per ton at 100 tons per day and a 2:1 stripping ratio. Flotation, if used, would cost $14 to $30 per ton. Other processing costs were not estimated because of the many possible end uses. Truck transportation for 50 mi would cost at least $14 per ton.

Pozzolan

Pozzolans are siliceous aluminous iron-bearing materials found in many volcanic tuffs, in diatomite, and in ash from coal burning. Pozzolan may be used to replace relatively expensive cement and may improve the properties of concrete. In 1985, 11.4 million tons of fly ash were consumed as pozzolan (Sam Tyson, American Coal Ash Association, oral commun., 1987). Ash from coal burning satisfies most of the pozzolan markets in the United States.

Chemical analyses show that most of the tuffaceous sediments, including some diatomite, in the Camp Creek study area meet chemical requirements for natural pozzolan for cement mixtures (American Society of Testing

Materials, 1985) (fig. 2, table 1, sites A, C, F); sediments at site J in the Cottonwood Creek study area are similar. Multiple tuffaceous beds hundreds of feet thick underlie the study areas. Only a small amount could be mined by surface methods, but the reserve base includes an inferred resource of at least 50 million tons of pozzolan-bearing material: 40 million tons in the Camp Creek study area, and 10 million tons in the Cottonwood Creek study area.

Additional tests (such as total available alkali, sulfur content, water content, pozzolan activity index, water requirement, cement strength, and concrete applications) would be needed before assuming that the material would be useful for a specific pozzolan application. January 1988 mining costs (Benjamin and Gale, 1984) for pozzolanic tuffs in the study areas were estimated at $7 per ton for surface mining of a 500,000-ton deposit at 500 tons per day with no stripping. Subsequent processing costs were not estimated, but truck haulage for 50 mi would cost at least $14 per ton. Use of marginally economic resources of tuffaceous sediments as pozzolan is unlikely in the near future because of the distance to markets and the competition from established sources. A market within 10 or 20 mi, such as dam or highway construction, could make economic use of pozzolan sediments from the study areas.

Sand and Gravel

Sand and gravel occurs extensively along Camp Creek and Cottonwood Creek. The alluvium at site D (fig. 2, table 1) is subangular to subrounded and composed mainly of basalt, andesite, and rhyolite. The gravel is pebbly to cobbly with numerous boulders. Along Cottonwood Creek and the lower reaches of Camp Creek, the alluvium is hundreds of feet wide and ten or more feet thick. Sand and gravel from the study areas would only be mined for local use such as road and dam construction. Estimated surface mining costs for sand and gravel, using the method of Benjamin and Gale (1984), are about $3.40 per ton ($5.10 per yd^3) assuming a 500,000-ton deposit (330,000 yd^3), 1,000-ton (700-yd^3)-per-day operation, and 1.5 tons per yd^3 (January 1988 costs). Subsequent processing costs were not estimated. Truck transportation for 10 mi would cost about $5.50 per ton ($8.25 per yd^3; January 1988 costs). Sand and gravel are considered to be a marginally economic resource of at least 2.5 million yd^3 in each of the study areas.

Stone (Dimension and Decorative)

Building stone is used in the United States for building construction (47 percent), monuments (26 percent), rubble (14 percent), curbing (8 percent), flagging (4 percent), and other uses (1 percent). Prices in Spokane, Wash., for rock similar to that in or near the study areas ranged from $50 per ton to about $130 per ton in 1988.

The slabby porphyritic Littlefield Rhyolite of Kittleman and others (1965) crops out along the road down Alder Creek to Cottonwood Creek (fig. 2, table 1, site L). Lichens and a yellow- to brown-weathering rind may cover the rhyolite; where fresh, the rhyolite is gray to yellow. Talus of slabby rhyolite lies along the road adjacent to the Cottonwood Creek study area. Broken slabs are 0.5 to 3.0 in. thick, 4 to 20 in. wide and 6 to 30 in. long, and slightly wavy to concave; they are hard and brittle, and have a glassy ringing sound when struck. Slabby stone such as this is used as decorative facing on walls, in fences, and as flagging. January 1988 cost of mining the slabby rhyolite along Alder Creek was estimated (using methods of Benjamin and Gale, 1984) at more than $9 per ton for a 200,000-ton deposit mined at 60 tons per day with no stripping. Cost of subsequent processing was not estimated. Truck transportation for 100 miles would cost about $15 per ton (January 1988 costs). The slabby rhyolite is considered to constitute inferred marginal reserves of at least 740,000 tons in and adjacent to the Cottonwood Creek study area.

Mineral Occurrences

Metallic Minerals

Samples of silicified brecciated volcanic rocks along the Shearing Plant fault (Hagood, 1963a, p. 133, 134) in the Camp Creek study area contain small amounts of gold, molybdenum, arsenic, antimony, barium, and tungsten (fig. 2, table 1, site B). Extensions of the Shearing Plant fault into the Cottonwood Creek study area are not known to be mineralized. Samples of red limonitic tuff in the Camp Creek study area, possibly in or near fault zones, also contain minor antimony. One sample of rhyolite breccia and one sample of fumerolic vesicular basalt (scoria) from the western part of the Camp Creek study area contain 7 parts per billion (ppb) and 8 ppb, respectively, of gold, about twice the expected amount for basalt (Krauskopf, 1979). Samples of brecciated opalized rhyolite from the Cottonwood Creek study area east of Gugle Ranch (fig. 2, table 1, site K) contain small amounts of arsenic, molybdenum, rubidium, tungsten, barium, lanthanum, and ytterbium.

None of the rock samples contain any metallic commodities in economic amounts. None of the alluvial samples contain detectable detrital gold or economic heavy minerals. The distribution and content of gold, antimony, barium, arsenic, molybdenum, and tungsten indicate mineralization in silicified breccia along the Shearing Plant fault (Hagood, 1963a), in limonitic tuff, and in opalized rhyolite breccia east of Gugle Ranch, but metallic contents are too low, by factors of about 100, to be economic.

Nonmetallic Materials

A few pounds of calcite crystals and fragments were found in float northeast of Gugle Ranch along Cottonwood

Creek in the Camp Creek study area (fig. 2, table 1, site G). The calcite fills 1- to 5-in. voids in a volcanic breccia, and most crystals are less than 1 in. across. Vugs filled by calcite are uncommon; only one piece in float was found. The calcite is mostly small, milky, and twinned and is not an optical grade.

Volcanic glass is abundant in the northern part of the Camp Creek study area as fragments and blebs in a coarse glassy tuff at least 150 ft thick. A yellow to brown matrix of clay and carbonate minerals makes up about 20 percent of the tuff. Glass from along the west boundary of the Camp Creek study area has a refractive index of 1.576, determined by oil immersion, that does not indicate hydration. Another sample (fig. 2, table 1, site E) is a glassy welded tuff with a slightly perlitic texture; its refractive index indicates hydration, and expansion testing indicates a noncommerical perlite.

In checking for zeolite minerals, much of the altered tuffaceous rocks and diatomite tested positive (Helfferich, 1964) for exchangeable cations, but only weak scattered X-ray diffraction peaks were found. Calcite, quartz, feldspar, kaolinite, smectite, and cristobalite were identified by X-ray diffraction, but no zeolites were found.

Recommendations for Further Work

Drilling and further testing, especially beneficiation tests, would give more information about the quality and uses of the diatomite. Pozzolan testing, marketing, and detailed cost studies could be performed. Additional sampling and mapping would help evaluate the low-grade mineralization along siliceous zones of the Shearing Plant fault (Hagood, 1963, p. 133–134), in opalized rhyolite breccia near Gugle Ranch, and in tuffs and breccias throughout the study areas.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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Geological Studies

The Camp Creek and Cottonwood Creek Wilderness Study Areas, which are joined along a section of Cottonwood Creek, are in the High Lava Plains subprovince of the Columbia Intermontane physiographic province. The surface geology consists of a continuous series of flat-lying mafic and silicic lava flows, pyroclastic deposits, and associated sediments, all of Miocene and (or) Pliocene age. At present, the composition of the basement rocks is unknown, but they could be composed of older basin material.

Individual rock units mapped in the study areas are in the same stratigraphic order as that proposed by Hagood (1963a, b) but are shown as only five map units on the generalized geologic map (fig. 2).

The oldest map unit in the area consists of basalts of the basaltic breccia phase of the unnamed igneous complex of Hagood (1963a). In the study area, these rocks are columnar-jointed porphyritic basalt flows containing large tabular plagioclase phenocrysts and vugs of various sizes.

The Crowley Formation of Hagood (1963a, b), which overlies the basaltic breccia, consists mostly of rhyolitic and basaltic lava flows, ash-flow tuffs, and associated sedimentary rocks.

Overlying these rocks is a unit consisting largely of basalt flows. The oldest rocks in this map unit consist of a sequence of basalt flows and volcanic breccias; the upper part consists of the Tims Peak Basalt.

Locally, the Wildcat Creek Welded Ash-Flow Tuff of Kittleman and others (1965) overlies part of the Crowley Formation.

The youngest map unit in the study areas is here designated as the "younger volcanic and associated sedimentary rocks." This unit consists of the Squaw Creek unit of Hagood (1963a) (a sequence of fine-grained vitric tuffs and porcelaneous rocks that are interbedded with shale and that may locally contain diatomite), an unnamed andesite, the basalt of Willow Springs, the Grassy Mountain Formation of Kittleman and others (1965) (interbedded basalt, volcanic and arkosic sandstone, ash, conglomerate, and pumice breccia), the Bully Creek Formation of Kittleman and others (1965) (interbedded volcanic sandstone, conglomerate, and claystone; tuff; basalt; and diatomite), and unnamed tuff breccia.

The study areas are traversed by a series of north-northeast-trending high-angle normal faults having offsets of tens to hundreds of feet. Few rocks along these faults are extensively altered.

Geochemical Studies

A reconnaissance geochemical survey was conducted in the Camp Creek and Cottonwood Creek Wilderness Study Areas in the summer of 1986. Minus-80-mesh stream sediments and heavy-mineral concentrates derived from them were collected at 31 sites, and rocks were collected from 17 sites for this study. Analytical data and a description of the sampling and analytical techniques are given in Jones and others (1988).

Rocks from 7 of the 17 sample sites contain elements having anomalously high values; 6 of these sites are in the east-northeastern part of the Camp Creek and Cottonwood Creek study areas. The rock samples contain anomalous values for molybdenum (5–20 parts per million, ppm), bismuth (2–4 ppm), arsenic (6–9 ppm), and zinc (up to 200 ppm). These anomalous concentrations, however, are not high enough to be considered more than intrinsic variations within the rock types of the study areas.

Analyses of the minus-80-mesh stream sediments show anomalous values for arsenic (5–25 ppm), bismuth (2–3 ppm), cadmium (1–1.6 ppm), manganese (up to 5,000 ppm), molybdenum (5–7 ppm), and zinc (200–240 ppm). These anomalous values are so low that they probably reflect only intrinsic variations within the rock types of the study areas.

Analyses of the heavy-mineral concentrates from the two study areas show no anomalous data.

Geophysical Studies

An aeromagnetic survey of the study areas was flown in 1976 and 1977 by the Geophysics Group at Oregon State University as part of a study of the Vale-Owyhee geothermal area (Boler, 1978). The aeromagnetic data were collected along parallel east-west flightlines spaced 1.0 mi apart at a constant flight elevation of 7,000 ft above sea level. The Earth's main field was subtracted from the data, which were then plotted by machine and hand-contoured at a scale of 1:62,500. A final residual map was drafted at a scale of 1:125,000.

Additional aeromagnetic data are available in the atlas on the Boise quadrangle (scale, 1:500,000) published for the Department of Energy (geoMetrics, Inc., 1979). These data consist of aeromagnetic profiles flown east-west by helicopter at an average height of 400 ft above ground and a profile spacing of 3 mi. Three of these profiles (numbers 80, 90, and 100) cross the study areas.

Variations in the Earth's magnetic field on an aeromagnetic residual map are, in general, caused by variations in the amounts of magnetic minerals in different rock units, magnetite being the common magnetic mineral in this area. Magnetic minerals, where locally either concentrated or absent, may cause a high or low magnetic anomaly that can be a guide to mineral occurrences or deposits. Boundaries between magnetic and relatively less magnetic rock units are located approximately at the steepest gradient on the flanks of the magnetic anomaly.

Because of the preponderance of lava flows and other volcanic rocks in this area, one might expect that the majority of the anomalies are caused by volcanic rocks. However, the survey aircraft was generally 2,000 to 3,500 ft above the surface of the ground in this area, a distance sufficiently great to suppress most of the short-wave-length anomalies generated by rocks at or near the surface. The contoured magnetic map shows a broad subcircular magnetic high about 8 mi in diameter and about 400 gammas in amplitude. This high is centered over the Cottonwood Creek Wilderness Study Area but extends to the northwest about halfway across the Camp Creek Wilderness Study Area. The high, because of its great width and form, represents a causative rock mass at least 5,000 ft thick which does not appear to be exposed and which may be an intrusion into the igneous complex that forms the volcanic basement in this area (Kittleman and others, 1967). The causative mass and the magnetic high are terminated on the east by the Shearing Plant fault. The economic potential of this possible intrusion is unknown. The intrusion roof, on the basis of local geologic structure, would probably be no higher than about 3,700 ft above sea level.

Another major magnetic feature is a distinctive northeast-trending magnetic low, about 6 mi long by 3 mi wide, located just outside the northwest border of the Camp Creek Wilderness Study Area. This anomaly is about 400 gammas in amplitude and correlates well with an uplifted oval basement area of the igneous complex. Two intrusive rhyolite plugs centered within this oval area display intense local magnetic lows having amplitudes in excess of 1,500 gammas at an altitude of 300 ft above ground (geoMetrics, Inc., 1979, line 80). The lows are caused by reverse remanent magnetization, certainly in the rhyolite plugs and perhaps also in the uplifted igneous complex. Another possible cause for the low might be a large concealed shallow-depth siliceous pluton related to the plugs and to the doming. The absence of significant rock alteration in this area suggests that there is little, if any, economic significance to these aeromagnetic observations.

A gravity survey of this same region has been described and interpreted by Lillie (1977). The average station spacing is about 5 mi, and 12 gravity stations are located within or near the two study areas. The data are presented as a complete Bouguer anomaly map having a contour interval of 2 milligals (mGal) and a reduction density of 2.67 grams per centimeter cubed. Two gravity features are apparent: (1) a linear gravity gradient trending north-south and sloping down to the west along the east border of the two study areas, and (2) a small gravity high of about 5 mGal located directly northwest of the Camp Creek Wilderness Study Area. The first feature probably is associated with the Shearing Plant fault on the east side of the study areas. The second feature correlates with the magnetic low described above and is probably caused by the uplifted rocks of the igneous complex. These gravity features probably have no economic significance in these study areas, although thermal springs and wells are associated with major north-south faults in the Vale Known Geothermal Resource Area located 45 mi to the northeast.

Aerial gamma-ray spectrometer measurements are available along the aeromagnetic profiles (geoMetrics, Inc., 1979). The anomalies are 3 to 4 standard deviations above the average values for the Boise quadrangle. Examination of these anomalies in relation to the geologic map of Kittleman and others (1967) shows that the anomalies appear to be associated with rocks of the Littlefield Rhyolite. The anomalies indicate that these rocks probably contain the largest amounts of uranium, potassium, and thorium in this part of the quadrangle. These amounts are probably within the normal ranges for this type of igneous rock and thus do not necessarily indicate any resources of economic significance.

Mineral and Energy Resource Potential

The Camp Creek and Cottonwood Creek Wilderness Study Areas have moderate mineral resource potential for an epithermal-vein-type gold deposit along the Shearing Plant fault (fig. 2). Both study areas have moderate mineral resource potential for hot-spring-type gold deposits throughout the area. The resource potential in both study areas is low for diatomite deposits in the eastern parts and for zeolite minerals, pozzolan, building stone, geothermal energy, and oil and gas over the entire area.

The Shearing Plant fault (fig. 2) is a high-angle normal fault trending about N. 10° E. Breccia zones, small quartz stringers, and silicified joints radiate from the fault in many places. Low-level geochemical anomalies occur in the stream sediments in the northeastern part of the study areas near the fault; some of the breccia zones show siliceous alteration. These data suggest resource potential for deposits of epithermal gold and (or) silver. Although the amount of alteration is small and the geochemical anomalies are low level, the geologic setting is similar to other areas that contain epithermal gold deposits in Malheur County (Wheeler, 1988). These data support moderate mineral resource potential (certainty level B) for a small deposit of gold and (or) silver somewhere along the Shearing Plant fault in both study areas.

Samples of altered rhyolite and basalt from the study areas contain 7 ppb and 8 ppb gold, respectively (Benham and Miller, 1988, p. 20). These values are in the background range for extrusive felsic rocks (0.1–113 ppb) and extrusive mafic rocks (0.1–230 ppb) (Boyle, 1979, p. 38). However, the presence of gold, the relatively high heat flow, the sporadic occurrence of opal, and the areas of brecciated volcanic rock in the study areas suggest the possibility of hot-spring-type gold mineralization (Berger, 1986). Wheeler (1988) notes epithermal gold prospects hosted by pyroclastic and sedimentary rocks in northern Malheur County; those rocks can be correlated with similar rocks in these study areas. These data suggest moderate mineral resource potential (certainty level B) for epithermal hot-spring-type gold deposits throughout the study areas.

Diatomite occurs in the younger volcanic and associated sedimentary rocks along the east side of both study areas (fig. 2) and is associated with laucustrine sediments. The limited quantity, low quality of the diatomite, distance to market, and the abundance of higher quality material in other parts of the surrounding area lead to the conclusion of low mineral resource potential (certainty level C) for minable diatomite in several areas of the eastern part of both study areas.

There is low mineral resource potential (certainty level B) for zeolite deposits throughout both study areas. Both areas are underlain by siliceous volcanic rocks that could be altered to zeolite minerals. Geothermal systems may occur in the study areas, as indicated by the presence of opalized rocks. These criteria suggest the possibility of zeolite deposits but do not necessarily indicate that they exist, thus the certainty level B.

Building stone resources occur in rhyolite of the Crowley Formation. Because both study areas are underlain by these rhyolites, both areas have potential for a deposit of usable building stone. However, large areas of this rhyolite, as well as other suitable slabby rhyolites, are exposed in adjacent and distant areas that are more suitable for exploitation. Therefore, the mineral resource potential for exploitable building stone in these study areas is low (certainty level C).

Siliceous tuffs suitable for use as pozzolan occur throughout both study areas; hence, both areas are considered to have resource potential for a pozzolan deposit. However, because the established industry source of pozzolan is a by-product of coal-burning operations and because there is overburden to be removed in the study areas, the mineral resource potential for pozzolan in the study areas is low (certainty level C).

Both study areas have low potential (certainty level C) for high-temperature (194 to 302 °F) geothermal energy resources. No thermal springs are known to exist in the study areas, and only small areas of hydrothermal alteration were found. However, the study areas have relatively high heat flow—approximately 100 milliwatts per square meter (Muffler, 1979, map 1). The potential for geothermal resources is also somewhat enhanced by the presence of four hydrothermal convection systems within a 50-mi radius of the study areas (Riverside Area, Little Valley Area, Neal Hot Springs, and Vale Hot Springs; Brook and others, 1979). These systems have estimated reservoir temperatures that range from 244±50 °F (Riverside Area) to 370±46 °F (Neal Hot Springs) (Brook and others, 1979).

There are no known occurrences of oil or gas in the study areas, nor are there any indications of any in the water wells. However, source beds of older basin material may underlie or be interbedded with the older rocks at depth (Fouch, 1983). The maturation level for stable hydrocarbons may have been exceeded in the older basin fill of the study area (Fouch, 1983), in which case any petroleum in the sediments would not have been preserved. However, because the thermal history has not been established, it is concluded that both study areas have low resource potential (certainty level B) for oil and gas.

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LEVELS OF RESOURCE POTENTIAL

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

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

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

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

U **UNKNOWN** mineral resource potential is assigned to areas where information is inadequate to assign a low, moderate, or high level of resource potential.

LEVELS OF CERTAINTY

A Available information is not adequate for determination of the level of mineral resource potential.

B Available information only suggests the level of mineral resource potential.

C Available information gives a good indication of the level of mineral resource potential.

D Available information clearly defines the level of mineral resource potential.

LEVEL OF RESOURCE POTENTIAL →

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

LEVEL OF CERTAINTY →

Abstracted with minor modifications from:

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

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RESOURCE/RESERVE CLASSIFICATION

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

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

GEOLOGIC TIME CHART

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

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

[1]Rocks older than 570 Ma also called Precambrian, a time term without specific rank.
[2]Informal time term without specific rank.

SELECTED SERIES OF U.S. GEOLOGICAL SURVEY PUBLICATIONS

Periodicals

Earthquakes & Volcanoes (issued bimonthly).
Preliminary Determination of Epicenters (issued monthly).

Technical Books and Reports

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

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

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

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Water-Resources Investigations Reports are papers of an interpretive nature made available to the public outside the formal USGS publications series. Copies are reproduced on request unlike formal USGS publications, and they are also available for public inspection at depositories indicated in USGS catalogs.

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