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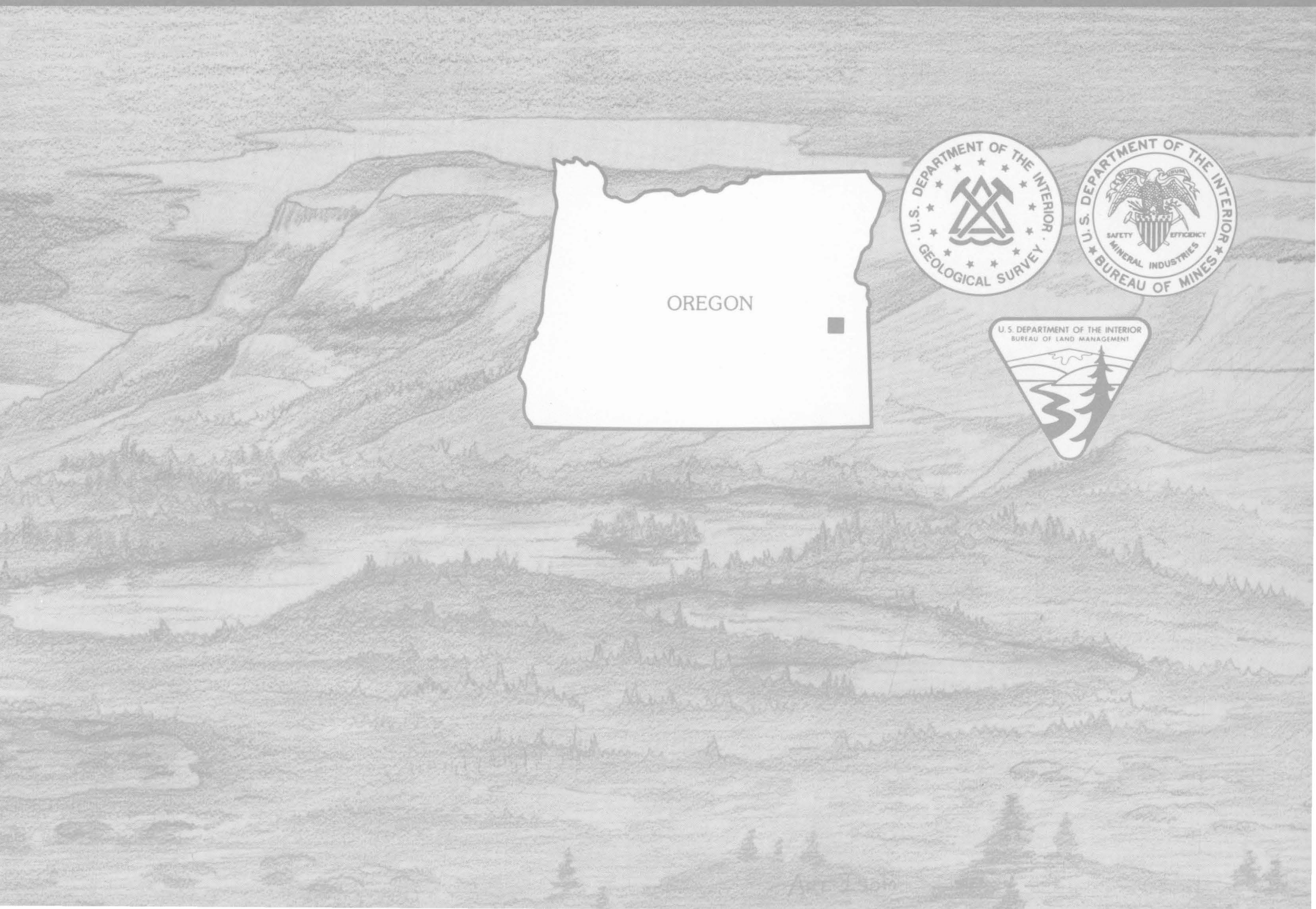
Mineral Resources of the Gold Creek and Sperry Creek Wilderness Study Areas, Malheur County, Oregon

U.S. GEOLOGICAL SURVEY BULLETIN 1741-E



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Chapter E

Mineral Resources of the Gold Creek and Sperry Creek Wilderness Study Areas, Malheur County, Oregon

By JAMES G. EVANS, JAMES G. FRISKEN, ANDREW GRISCOM, and DON L. SAWATZKY
U.S. Geological Survey

MICHAEL S. MILLER
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1741

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
EAST-CENTRAL OREGON

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
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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 on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Gold Creek (OR–003–033) and Sperry Creek (OR–003–035) Wilderness Study Areas, Malheur County, Oregon.

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Mineral Resources of the Gold Creek and Sperry Creek Wilderness Study Areas, Malheur County, Oregon

By James G. Evans, James G. Frisken, Andrew Griscom, *and* Don L. Sawatzky
U.S. Geological Survey

Michael S. Miller
U.S. Bureau of Mines

SUMMARY

Abstract

At the request of the U.S.Bureau of Land Management, the Gold Creek (OR–003–033) and Sperry Creek (OR–003–035) Wilderness Study Areas, comprising approximately 15,780 and 5,600 acres, respectively, were evaluated for mineral resources and mineral resource potential. Throughout this report, "wilderness study area" and "study area" refer to the combined 21,380 acres for which mineral surveys were requested. The U.S. Geological Survey and the U.S. Bureau of Mines conducted geologic, geochemical, and geophysical surveys to assess the identified mineral resources (known) and mineral resource potential (unknown) of the study area. Field work for this report was carried out in 1987, 1988, and 1989.

The study area contains more than 100,000 short tons (st) of diatomite, 80,000 st of building and decorative stone, and large amounts of basalt suitable for crushed aggregate or the production of basalt fiber. The study area also contains 865,000 yd^3 of sand and gravel resources. In addition, fanglomerate, possibly suited for sand and gravel, covers 3,100 acres. Gold, optical calcite, zeolite, and perlite have been found locally in small uneconomic amounts. A geothermal energy occurrence is present.

Part of the Gold Creek Wilderness Study Area has high mineral resource potential for gold, and a very small part of that has low resource potential for geothermal energy resources. The northern part of the Gold Creek Wilderness Study Area and the eastern part of the Sperry Creek Wilderness Study Area have moderate mineral resource potential for gold, silver, and mercury. The entire study area has low potential for oil and gas energy resources.

Manuscript approved for publication, August 20, 1990

Character and Setting

The Gold Creek and Sperry Creek Wilderness Study Areas (fig. 1) are located about 33 mi southwest of Vale, Oreg. The study area is part of the Owyhee Plateau south of the Malheur River and consists of several deep canyons cut into a broad plateau of flat uplands, low hills, and mesas. These canyons are incised as deeply as 1,400 ft into the plateau. The Malheur River, along the north side of the study area has cut down about 2,400 ft through the plateau. The study area is underlain by Miocene or older, Miocene, Pliocene, and Quaternary sedimentary, volcanic, and pyroclastic rocks and deposits (fig. 2; see "Appendixes" for geologic time chart). Numerous steep faults cut the study area.

Identified Resources

More than 100,000 short tons (st), of marginally economic diatomite resources were identified inside the east boundary of the study area, and at least 2,000,000 st were identified outside the eastern boundary. The study area contains 80,000 st of marginally economic building and decorative stone and large amounts of basalt suitable for crushed aggregate or production of basalt fiber. Subeconomic resources of sand and gravel total 865,000 yd^3, and an additional 3,100 acres within the study area are underlain by fanglomerate that may be suitable for sand and gravel production. Gold, optical calcite, zeolite, and perlite are present in the study area in small uneconomical amounts. A geothermal energy occurrence, possibly suitable for domestic space heating, is present along the north boundary of the study area.

Mineral Resource Potential

Part of the north-central Gold Creek Wilderness Study Area has high mineral resource potential for gold, and a small part of that area along the north boundary has low resource potential for geothermal energy. A large part of the northern Gold Creek Wilderness Study Area and the eastern part of the Sperry Creek Wilderness Study Area have moderate resource potential for gold, silver, and mercury. The entire study area has low potential for oil and gas energy resources.

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 the 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 and energy resources by determining geologic units and structures, possible environments of mineral deposition, presence of geochemical and geophysical anomalies, and application of 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

The Gold Creek (OR–003–033) and Sperry Creek (OR–003–035) Wilderness Study Areas cover 21,380 acres of the Owyhee Plateau south of the Malheur River (fig. 1). Several steep, rocky canyons, including the canyons of Gold Creek and Sperry Creek, cut into the plateau. These canyons and the steep-sided intervening ridges make up most of the

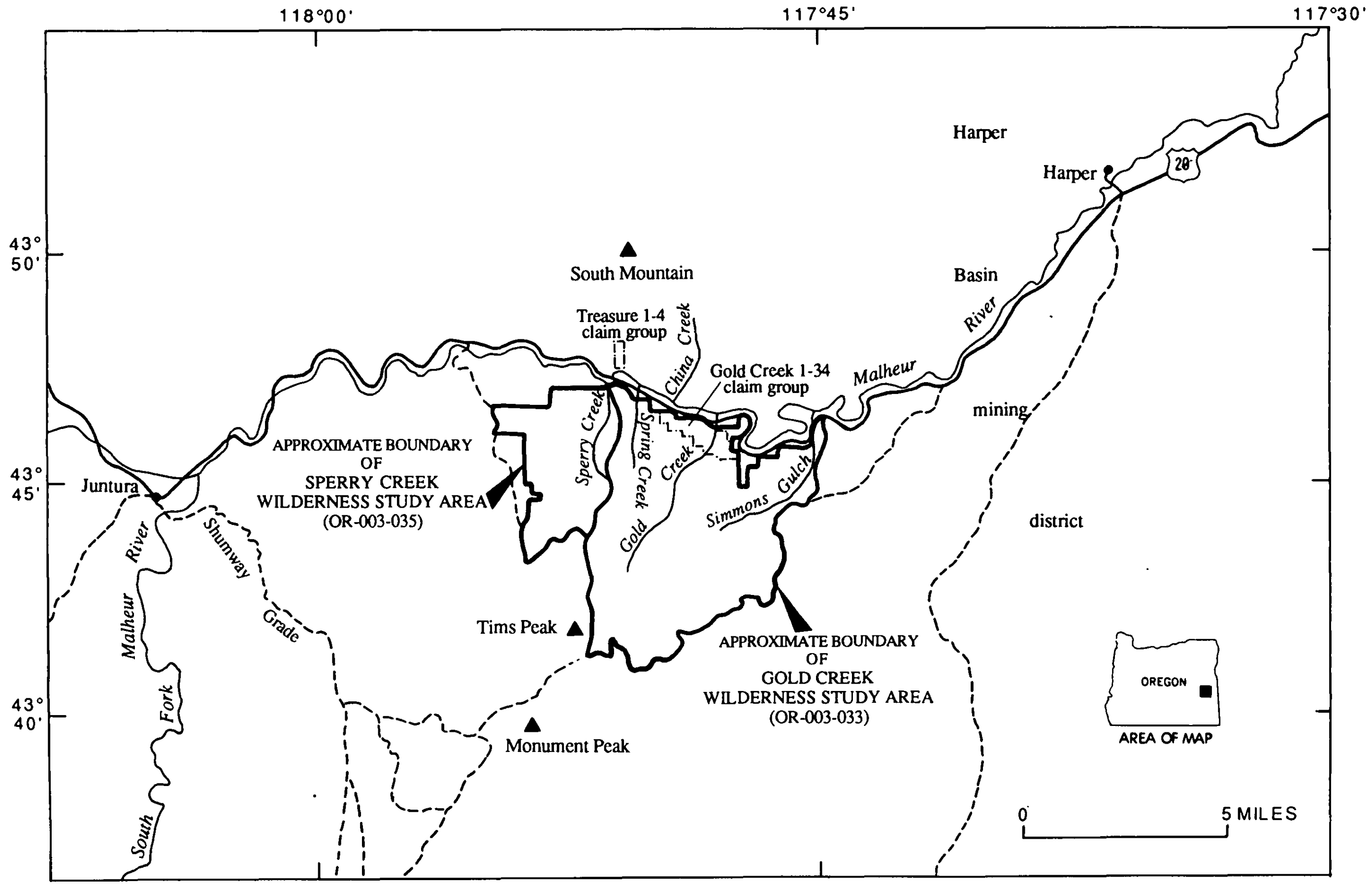

Figure 1. Index map showing location of Gold Creek and Sperry Creek Wilderness Study Areas, Malheur County, Oregon. Dashed lines, unpaved roads.

study area. A small part of the southern part of the study area is on the flat uplands of the plateau at the heads of the canyons. The total relief is 2,662 ft from a low point of 2,660 ft in the northeast corner of the Gold Creek Wilderness Study Area along the Malheur River to 5,322 ft in the southwest corner near Tims Peak. Some of the canyons are as deep as 1,400 ft. The arid climate supports sagebrush, rabbit brush, and sparse native grasses. Riparian areas and springs support a greater variety of plants, including low-growing willows, bitter cherry, golden currant, rose, sedges, and rushes. Parts of the study area are used for cattle and sheep grazing. The study area also supports mule deer, antelope, coyote, and numerous species of small mammals, birds including raptors, and reptiles including the western diamondback rattlesnake. The northern part of the study area provides critical winter range for deer and antelope.

Dirt roads and jeep trails traverse much of the boundary and cross parts of the study area (fig. 1). Access to most of the study area is easiest near its north boundary from U.S. Highway 20, which follows Malheur River canyon. This highway connects with dirt roads that ascend South Trail Creek on the west side of the study area and the North Fork Squaw Creek along the east side of the study area. Branching jeep trails provide access to the southern part, which can also be reached by better jeep trails that branch from the Shumway Grade gravel road south of Juntura, 11 mi west of the study area.

Previous and Present Investigations

Geologic mapping that included parts of the study area was carried out by Hagood (1963) at the scale of 1:31,680 and by Haddock (1967) at the scale of 1:63,360. Their work was incorporated into a treatise on the stratigraphy of the region by Kittleman and others (1965) and a geologic map of the region by Kittleman and others (1967) at the scale of 1:250,000. Walker (1977) later incorporated Hagood's and Haddock's mapping into a geologic map of eastern Oregon at the scale of 1:500,000. Reconnaissance geochemical studies and initial mineral resource appraisals of many wilderness study areas of eastern Oregon, including the Gold Creek and Sperry Creek Wilderness Study Areas, were made by Gray and others (1983) and Bukofski and others (1984).

The U.S. Geological Survey carried out field investigations in the study area during 1988. This work included geologic mapping at the scale of 1:24,000, geochemical sampling, and review and interpretation of geophysical surveys (gravity, aeromagnetic, gamma ray spectrometer, remote sensing).

The U.S. Bureau of Mines investigation was conducted by personnel from the Western Field Operations Center, Spokane, Wash., during 1987, 1988, and 1989. Details of sampling methods and analyses are reported by Miller (1989).

APPRAISAL OF IDENTIFIED RESOURCES

By Michael S. Miller
U.S. Bureau of Mines

Methods

Initial studies of the Gold Creek and Sperry Creek Wilderness Study Areas included a literature search and an examination of Malheur County and U.S. Bureau of Land Management mining claim and mineral lease records. U.S. Bureau of Mines production records were also searched. Field studies, including a search for all mining activity and mineralized zones within the study area, were conducted during 16 days between May and August 1988. Mineralized zones were examined, mapped, and sampled. Those close to the study area were also examined to determine if they extended into the study area and to understand the regional mineralization. Ground and air reconnaissance were used to search for extensions of mineralized zones from known mineral sites. Sample collections included 188 rock and 12 alluvial samples (Miller, 1989). The results of the investigation are summarized in table 1.

Mining History

Small pits and trenches of unknown age were found along quartz veins west and southwest of the mouth of Gold Creek. Underground workings, not found in this study, reportedly were dug about 1900 by Chinese miners at hot springs along the north boundary of the study area (fig. 2) (Ben Jordan, oral commun., 1988). China Creek, north of the Malheur River, may have been named to commemorate these early miners. The Frying Pan and Harry Boy lode claims in the study area along Gold Creek were recorded in 1913 (Miller, 1989). A group of four placer claims, the Fiery, Firebrand, Firetrap, and Fire Bug, date from 1917 and were described as lying about 1 mi east of the Gold Creek Wilderness Study Area. The Gold Peak lode claim, location uncertain, was recorded in 1925. In 1928, the Lost Hope and Fabled Goose lode claims were located near the mouth of Gold Creek. The Treasure 1-4 lode claims were located in 1958 on a hill north of the Malheur River across from Sperry Creek. The Morning Side lode claim was staked in 1967 west of the mouth of Gold Creek. The Gold Creek No. 1 lode claim was located about 1.5 mi southwest of the mouth of Gold Creek in 1979 by Ben Jordan, Raymond Jordan, and Curt Hysell. Manville Products Corporation staked 34 lode claims near the mouth of Gold Creek in 1988. Most of the older claims were not found in our 1988 studies. Other current activity is in the Harper Basin mining district, about 15 mi east of the study area, where Manville was investigating diatomite occurrences in 1987 (Ramp, 1988, p. 42–43) and American Copper and Nickel Company, Inc., was exploring for gold in 1988 (Ferns, 1989, p. 29). Diatomite is being mined by Eagle-Picher Industries at Drinkwater Pass, about 30 mi northwest of the study area. About 40 mi southeast of the study area, Teague Mineral Industries is mining bentonitic clay and zeolites. Quarries northeast of the study area along U.S. Highway 20, have been operated more or less continuously for decades to supply stone and aggregate for construction and road maintenance. No mineral patents and no oil and gas or geothermal energy leases or applications are known for the study area.

Appraisal of Commodities Examined

Diatomite

Diatomite that could be used for filter aids (69 percent), fillers (16 percent), and other uses (15 percent) occurs in and adjacent to the study area. At least 30 acres of diatomite having an estimated thickness of 5 ft occurs adjacent to and inside the east boundary of the Gold Creek Wilderness Study Area. Marginally economic resources of at least 100,000 short tons (st) of diatomite occur inside the study area, and about 2,000,000 st occur east of the study area boundary in beds about 10 ft thick. Diatomaceous samples from the Fiery Placer mining claim group are from thin, silty, sandy, tuffaceous beds and do not constitute resources.

Diatomite samples from east of the study area have block densities of 32 to 43.5 pounds per cubic foot (lbs/ft^3) and an average block density of 36.8 lbs/ft^3. Samples used for resource estimates contain an average of 77.6 percent silica (SiO_2), 5.04 percent alumina (Al_2O_3), and 2.26 percent iron oxide (Fe_2O_3) and had an average loss on ignition of 11.86 percent. Moore (1937, p. 113) considered diatomite having a block density of less than 30 lbs/ft^3 to be excellent; block densities from 30 to 35 lbs/ft^3 are considered good, those from 35 to 40 lbs/ft^3 are fair, and those greater than 40 lbs/ft^3 are poor. Diatomite samples in and east of the Gold Creek Wilderness Study Area, therefore, are rated as poor to good quality; however, for some uses, denser diatomite is required.

Preliminary surface mining costs for diatomite were estimated by the methods of Benjamin and Gale (1984) using January 1988 costs. A 500,000-st deposit mined by open-pit methods at 100 st per day would cost from an estimated \$8 per st (\$/st) with no stripping to \$21/st with a 2:1 stripping ratio. Although other beneficiation methods are possible, flotation has been tested by the U.S. Bureau of Mines for impure diatomite (Norman and Ralston, 1940). Flotation concentration costs were estimated at \$30/st for a 500,000-st deposit mined at 100 st per day. Additional processing costs were not estimated because of the many possible end uses. Transportation for 50 mi at 25 mi per hour (mph) in 25-ton trucks was estimated to cost about \$14/st. Concentration by flotation or other methods would lower total transportation costs. The diatomite beds in and adjacent to the Gold Creek Wilderness Study Area are considered to be marginally economic inferred resources (U.S. Bureau of Mines and U.S. Geological Survey, 1980, p. 2) because of their low grade and the competition from established mines, primarily from Eagle-Picher's mine only 30 mi away and from others in California and Nevada (Meisinger, 1989, p. 50-51).

Stone

Weathered lichen-covered stone in the study area, mainly basalt, andesite, and rhyolite, breaks into irregular chunks and slabs that can be used for wall facing, flagging, and decorative purposes. At least 2 mi^2 of the study area are covered almost continuously by stones of this type. One piece of decorative stone weighing 150 lbs is estimated to occur on each 100 square ft (ft^2), and, therefore, 1 square mile of land is estimated to contain 20,000 st of stone suitable for landscaping. Each 100 ft^2 also contains about five pieces of stone weighing 30 lbs apiece, so the same square mile is estimated to contain 20,000 st of stone suitable for wall-facing. Preliminary costs for mining decorative stone in the study area were estimated by the methods of Benjamin and Gale (1984). Cost of mining stone at the surface, at 50 st/day, was estimated to be about \$14/st (January 1988 costs). Transporting stone in 25-ton trucks for 150 mi at 45 mph was estimated to cost about \$22/st (January 1988 costs). Similar rock in Boise, Idaho, was selling for between \$100 and \$200/st retail in 1988. Therefore, building and decorative stone in the study area is considered to be a marginal economic inferred resource (U.S. Bureau of Mines and U.S. Geological Survey, 1980, p. 2) of at least 80,000 st. Decorative stone might be mined from the study area when existing resources nearer markets are depleted.

Basalt

Stone quarries near U.S. Highway 20 supplied large quantities of crushed rock, mainly basalt, that were used during highway construction. Two quarries, from which a minimum estimate of 1 million st of stone were mined are about 0.5 mi east of the Gold Creek Wilderness Study Area. No resources of stone for crushing were estimated for the study area because large quantities of suitable basalt of good quality outside the study area would probably be mined first.

Basalt fibers can be produced from basalt similar to that in the study area. Although this use is currently limited, future developments in the field of thermal insulation and high-strength reinforcement may result in significant markets. Basalt fibers can replace glass fibers in many applications (Subramanian and others, 1977). Samples of basalt from the northeastern part of the study area contain an average of about 16 percent Al_2O_3, 12 percent Fe_2O_3, 5 percent magnesia (MgO), 48 percent SiO_2, and 1.8 percent titania (TiO_2). This composition, inferred to be typical throughout the study area, is similar to that of basalts reportedly used for basalt fiber production (Subramanian, 1977, p. 5). Basalt suitable for production of fibers occurs throughout the study area and is also abundant in the region. Even though the quantity and quality of basalt in the study area would probably allow mining the rock for fiber production, the basalt is unlikely to be mined in the future because of the abundance of similar rock closer to population centers.

Sand and Gravel

Sand and gravel occurs on benches in the northern part of the study area. Large amounts of sand and gravel also occur near the mouths of some of the drainages in the study area. The sand and gravel, which is derived from basalt and rhyolite, consists of silt, sand, pebbles, cobbles, and boulders that are subrounded to angular. Constituent clasts include opal, chalcedony, obsidian, and vitrophyre.

Sand and gravel that covers about 30 acres of terraces in the Gold Creek Wilderness Study Area is estimated to average 15 ft in thickness and constitute 700,000 yd^3. Another sand and gravel deposit along Gold Creek is estimated to be 15 ft thick, 200 ft wide, and 2,000 ft long and constitutes about 220,000 yd^3, about 75 percent of which is in the study area. A sand and gravel deposit in Simmons Gulch is estimated to be 15 ft thick, 300 ft wide, and 2,500 ft long and constitutes about 400,000 yd^3 but is just outside the study area. Approximately 865,000 yd^3 of sand and gravel are present in the study area in these deposits. Sand and gravel deposits also occur along most of the drainages and in alluvial fans that cover some ridges in the northern part of the study area. Approximately 3,100 acres underlain by fanglomerate as much as 100 ft thick is another possible source of sand and gravel in parts of the study area. The sand and gravel in the fanglomerate is not as accessible as the other sand and gravel, for which volume estimates were made, and the fanglomerate also contains more silt and clay. The sand and gravel resources may be used locally for minor road construction or concrete production, although large accumulations of sand and gravel along the Malheur River would probably be mined first. Therefore, the sand and gravel in the study area constitute inferred subeconomic resources.

Other Industrial Materials

In the northern part of the study area, much low-grade calcite and small quantities of calcite of possible optical quality (Hughes, 1941, p. 4-5) occur in amygdules and breccia zones in basalt. Small quantities of optical calcite are used for splitting light beams and for polarizing attachments for microscopes. The calcite in the study area occurs as amygdules and as cement in scattered areas of basalt breccia and is associated with fibrous radiating mordenite and quartz. Some amygdules are two or more inches across, and some breccia zones are as much as 1 ft thick and tens of feet long; some calcite crystals are as much as 3 in. across. Most of the calcite is milky, fractured, or twinned, but an estimated 1 percent or less of the calcite is of optical quality. Most of the optical calcite is in occasional pieces that are less than 0.5 in. by 0.5 in. by 1.0 in. Because a calcite prism 0.5 in. by 0.5 in. by 1.0 in. may sell for about $25 according to Edmund (1989, p. 113), grade and value of the calcite in the study area may be adequate for mining, but the market is small.

Abundant perlite float was found near the mouth of Simmons Gulch in the northeast corner of the Gold Creek Wilderness Study Area, but no perlite was found in outcrop. The perlite is probably from small or poorly exposed altered glassy zones in rhyolite and welded tuff. No perlite resources are indicated for the study area.

White to gray, fibrous, radiating acicular mordenite, a zeolite mineral, was found in amygdules in basalt flows and in flow-top basalt breccia in the northeastern part of the Gold Creek Wilderness Study Area. The mordenite is in masses less than 3 in. thick and 1 ft across and constitutes less than 10 percent of the rocks. It is associated with calcite, quartz, epidote, and chlorite. The mordenite was

Table 1. Summary of identified mineral resources and occurrences in the Gold Creek and Sperry Creek Wilderness Study Areas, Malheur County, Oregon

["Occurrence" indicates commodity is too low grade, too market dependent, or too small to classify at this time. st, short tons]

Commodity	Resource estimate	Classification
Diatomite----------	Greater than 100,000 st in study area; greater than 2,000,000 st outside study area.	Marginally economic resource.
Stone (decorative and building).	Greater than 80,000 st.	Marginally economic resource.
Basalt (fiber)------	Large quantity, but no resources estimated.	Occurrence; market dependent.
Sand and gravel --	865,000 yd^3---------	Subeconomic resource; market and transport dependent.
Gold----------------	Low grade----------	Occurrence.
Calcite (optical) --	Small; no resource estimated.	Occurrence; market dependent.
Zeolite-------------	Small----------------	Occurrence.
Perlite--------------	Small----------------	Occurrence.
Geothermal resources.	Small; no resource estimated.	Occurrence.

identified by X-ray diffraction and optical petrography. The amount of mordenite in the study area is too small to mine.

Gold and Associated Minerals

Gold, arsenic, antimony, bromine, mercury, molybdenum, and tungsten are concentrated in mineralized zones possibly related to older hot springs in the northern part of the study area. Most gold mineralization occurs in or adjacent to a vertical northwest-striking quartz-vein system. Average width of the principal vein is 2.25 ft over a length of at least 4,700 ft. The vein extends northwest beyond the north boundary of the study area and may extend farther to the southeast below overburden. In general, the vein system is narrow, lenticular, and discontinuous. A total of 24 chip samples and 114 grab samples was taken from the vein system and surrounding wall rocks in the Gold Creek 1-34 claim group (fig. 1). Of these samples, 70 contain 5 or more parts per billion (ppb) gold. The maximum concentration of gold is 1,960 ppb in a thin quartz vein, and 18 samples of quartz veins containing detectable amounts of gold average 440 ppb. Maximum gold concentration in basalt is 220 ppb and 33 samples of basalt containing detectable amounts of gold average 30 ppb. Antimony (maximum 517 parts per million, ppm), arsenic (maximum, 1,860 ppm), bromine (maximum, 15 ppm), mercury (maximum, 0.01 percent), molybdenum (maximum, 1,890 ppm), and tungsten (maximum, 508 ppm) occur in the quartz vein and, more commonly, in the wall rock near the vein. Sodium is depleted in areas of greatest gold concentration. Gold was identified in the quartz veins by scanning electron microscope-microprobe analysis. Accessory minerals associated with the gold include argentite, barite, bornite, cassiterite, galena, molybdenite, and powellite. On the basis of surface indications, mining the quartz vein by underground methods would not be feasible because of the narrow, discontinuous nature of the vein system and the low average gold content of the mineralized zone, which includes quartz and the adjacent mineralized basalt. However, the vein suggests a potential for gold at depth (see section on "Mineral and Energy Resource Potential"), and exploration is recommended (Miller, 1989).

The Treasure 1-4 lode claim group is about 0.5 mi north of the study area on the north side of the Malheur River. The claims are in much fractured basalt and welded tuff. Maximum amount of gold in six samples from these claims is 6 ppb, a quantity too low to be mined at present market value.

Quartz-cemented rhyolite breccia and siliceous veins are exposed along vertical, north-striking fault zones in Simmons Gulch in the northeastern part of the Gold Creek Wilderness Study Area. The veins contain red, brown, and purple chalcedony and opal. One of the 13 rock samples contains detectable gold at 9 ppb. One sample contains 176 ppm arsenic, and two samples contain 1,800 and 1,400 ppb mercury and 71.2 and 59.8 ppm antimony, respectively. Some samples contain detectable amounts of molybdenum (19 ppm maximum) and tungsten (18 ppm maximum). These analyses do not indicate minable grades of any elements but do indicate epithermal mineralization in the rhyolite in Simmons Gulch.

Average gold content of 12 reconnaissance alluvial samples is 0.0001 ounces per cubic yard (oz/yd^3), or less if boulders are factored into the estimate. This is equivalent to \$0.04 per cubic yard (\$/yd^3). Maximum amount of gold in alluvial samples from Simmons Gulch was about 0.0008 oz/yd^3, worth about \$0.32/yd^3. The source of gold in Simmons Gulch was not identified but is additional evidence of mineralization there. The value estimates were made by assuming that the gravel expands about 25 percent when excavated and that the gold is pure and worth about \$400 per ounce. Amounts of gold in alluvial samples are too small to be mined at this time.

No economic accumulations of gold or other associated elements were identified in the study area. Mining and beneficiation costs would exceed the value of the gold by a factor of at least 20 times.

Geothermal Energy

Hot springs occur along the north boundary of the Gold Creek Wilderness Study Area in an abandoned oxbow of the Malheur River where highway fill has created a pond that is approximately 500 ft by 200 ft. The hot springs have deposited low water-level tufa mounds about 30 ft across. The thinly laminated tufa is white with orange, yellow, and black staining. An old siliceous tufa deposit on the hillside to the south is about 30 ft above the springs and 100 ft across. Basalt flows near the hot springs and tufa deposits are cut by thin, siliceous, high-angle quartz veins surrounded by argillic and limonitic alteration. These veins and areas of argillic, limonitic basalt are hundreds of feet across, include the steep northwest-striking quartz-vein system described above, and are probably related to older hot springs activity.

Four spring orifices emit water at 157 °F in the early summer and 163 °F in the autumn after the flow rate decreases. Visual observations indicate that the flow of each hot spring is about 10 gallons per minute. The springs are bubbling, and the escaping gases have a faint odor of sulfur. The temperature of the water is high enough to permit direct use for domestic heating, but the flow rate is small. Drilling and development could increase the rate of energy production. In this report, however, the geothermal area is classified as an occurrence.

Oil and Gas

Traces of oil at the hot springs are indicated by thin, discontinuous, coalescing, iridescent films (see Emmons, 1921, p. 24). Four samples of rocks were collected near the springs from two high-angle faults that could have acted as conduits, but they contain no detectable hydrocarbons (0.05 percent lower limit of detection). Other samples of rock from vertical fault zones throughout the study area also tested negative for soluble hydrocarbons (see Emmons, 1921, p. 28). Bubbles rising at the hot springs were not flammable. Source of the oil trace was not identified. The oil at the the hot springs could be contamination from petroleum products used during road construction in the recent past or from automobile engine oil that may wash off the highway during sporadic heavy rains.

Recommendations for Further Study

Additional geologic mapping, geochemical sampling, and geophysical studies are needed to further evaluate gold occurrences at three sites in and near the study area: the Gold Creek 1-34 claim group, the Treasure 1-4 claim group, and along Simmons Gulch. Drilling the quartz-vein system in the Gold Creek 1-34 claim group might detect gold sources at depth.

Mining costs, beneficiation methods, and markets for specific applications should be studied before attempting to mine diatomite, basalt, stone, and (or) sand and gravel, and detailed sampling would be needed before mining diatomite. More detailed geologic mapping is recommended to find the source of perlite boulders in Simmons Gulch. In-place perlite occurrences may have economic value.

Testing of the hot springs area is recommended to determine geothermal reservoir characteristics. In order to evaluate the occurrence of geothermal energy that is known to be present in the Gold Creek Wilderness Study Area and to identify geothermal energy resources, instrument measurements of flow and variation in flow as well as variations in temperature must be made.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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Geology

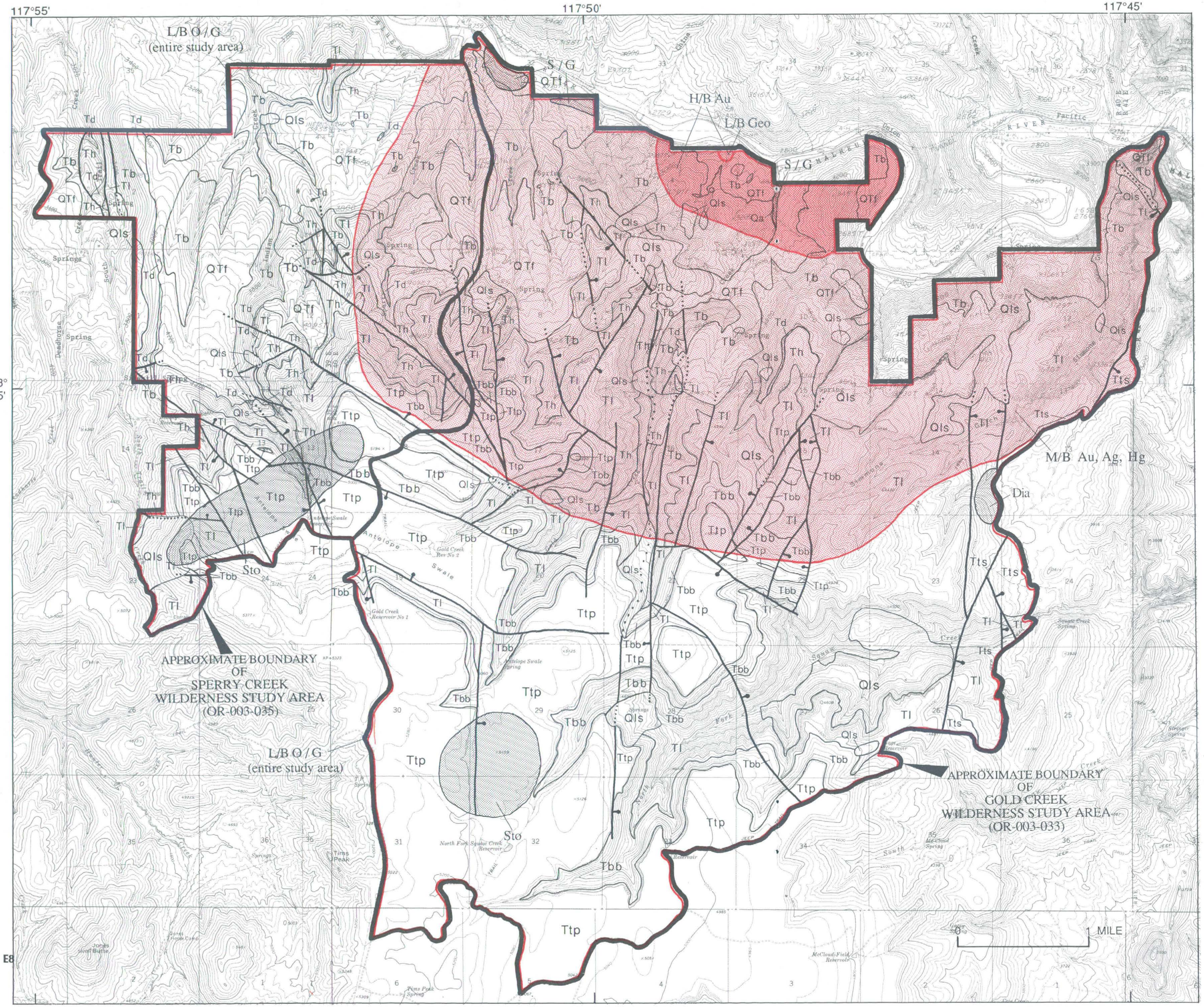
The Gold Creek and Sperry Creek Wilderness Study Areas are underlain by a flat-lying sequence of Miocene through Holocene sedimentary, volcanic, and pyroclastic rocks (fig. 2). The following rock descriptions combine field observations made during the present study and rock descriptions from Hagood (1963), Kittleman and others (1965), and Haddock (1967).

The oldest rock unit in the study area consists mostly of alternating layers of aphanitic and porphyritic basalt and basalt flow breccia, herein called the basaltic complex; it is equivalent to the unnamed igneous complex of Kittleman and others (1965). As much as 10 percent of the unit consists of sandstone, siltstone, red welded basaltic tuff, and hyaloclastite beds as thick as 40 ft. The hyaloclastite consists of angular vesicular basalt fragments and pale-brown silt. Some of the porphyritic basalt contains plagioclase phenocrysts as long as 1 in. According to Hagood (1963), the basalt is composed of labradorite and clinopyroxene, as the major constituents, and minor opaque iron oxide, glass, olivine, and alteration products. Kittleman and others (1965) estimated the maximum thickness of the unit to be 2,000 ft in Malheur Canyon.

The Dinner Creek Welded Ash-Flow Tuff (Kittleman and others, 1965) is a rhyolitic ash-flow tuff that stratigraphically overlies the basaltic complex but is commonly absent in the study area. The most conspicuous part of this unit is a cliff-forming, light-brown, densely welded tuff that is partly devitrified, contains lithophysae as much as 1 in. across, and contains phenocrysts (plagioclase, anorthoclase, hypersthene) and lithic fragments (pumice, basalt) as long as 4 in. Unwelded to partly welded horizons occur above and below the strongly welded part. The total thickness of the unit varies, but the maximum is 80 ft; commonly only about 20 ft or less of the strongly welded tuff is visible. On the basis of isopachs of the tuff, which indicate an increasing thickness of the unit to the northwest, Haddock (1967) suggested that the tuff was extruded from a silicic vent at Castle Rock, 24 mi northwest of the study area.

The Hunter Creek Basalt (Kittleman and others, 1965) overlies the Dinner Creek Welded Ash-Flow Tuff and the basaltic complex where the Dinner Creek is absent. The Hunter Creek is a black, fine-grained and aphanitic basalt that typically breaks into irregular angular fragments about 8 in. across. Hagood (1963) identified labradorite, clinopyroxene, and glass as the major constituents and minor opaque iron oxide.

The Littlefield Rhyolite (Kittleman and others, 1965), overlying the Hunter Creek Basalt, is a gray, porphyritic, generally flow-foliated rhyolite that usually weathers to thin plates and has a brown oxide patina on the weathered surfaces. The lowermost part of the unit locally consists of 10 to 20 ft of partly welded tuff or unconsolidated tuffaceous siltstone and sandstone, which is usually succeeded by a zone of black vitrophyre of varied thickness. The unit also contains obsidian, scoriaceous zones possibly related to flow margins, and black perlitic vitrophyre autointrusions. In places, the unit contains beds of white to pale-brown lithic tuff as much as 40 ft thick that clearly separate flows in the unit. As much as 4 percent of the typical rhyolite consists of sanidine, andesine, orthoclase, clinopyroxene, hypersthene, and magnetite phenocrysts as long as 0.0625 in. in a



EXPLANATION

Area having high mineral resource potential (H)

Area having moderate mineral resource potential (M)

Area having low mineral resource potential (L)

Level of certainty of assessment

B Data only suggest level of potential

Area having identified mineral resources for commodities as labeled

Commodities

Au	Gold
Ag	Silver
Dia	Diatomite
Geo	Geothermal resources
Hg	Mercury
O/G	Oil and gas
Sto	Building and decorative stone
S/G	Sand and Gravel

Geologic map units

Qa	Alluvium (Quaternary)
Qls	Landslide deposits (Quaternary)
QTf	Fanglomerate (Quaternary and Pliocene)
Tts	Tuff and tuffaceous siltstone (Pliocene or Miocene)
Ttp	Tims Peak Basalt of Kittleman and others (1965) (Miocene)
Tbb	Pillow-basalt breccia (Miocene)
Tl	Littlefield Rhyolite of Kittleman and others (1965) (Miocene)
Th	Hunter Creek Basalt of Kittleman and others (1965) (Miocene)
Td	Dinner Creek Welded Ash-Flow Tuff of Kittleman and others (1965) (Miocene)
Tb	Basaltic complex (Miocene or older)—Equivalent to unnamed igneous complex of Kittleman and others (1965)

Contact

Fault—Dotted where concealed. Bar and ball on downthrown side

Figure 2. Mineral resource potential, identified mineral resources, and generalized geologic map of Gold Creek and Sperry Creek Wilderness Study Areas, Malheur County, Oregon. Base from U.S. Geological Survey 1:24,000, Monument Peak, Tims Peak, 1972; Jonesboro, Namorf, South Mtn., 1990. Contour intervals 40 and 20 ft. Geology mapped by J.G. Evans, 1988.

glassy matrix that is locally devitrified and, in places, contains abundant spherulites as much as 0.5 in. across. The rhyolite has a minimum thickness of 250 ft along the west boundary of the study area and thickens eastward to at least 880 ft in the northeastern part of the Gold Creek Wilderness Study Area, where it rests on progressively older rocks that locally include the basaltic complex. Most of the transition of the underlying units from the Hunter Creek Basalt to the basaltic complex is concealed beneath landslides. The Littlefield Rhyolite thickens to at least 1,200 ft (maximum exposed thickness, base not exposed) in upper Simmons Gulch in the area of an aeromagnetic high (fig. 3). The high may reflect the presence of a circular rhyolite vent that may be as wide as 4 mi through which the rhyolite was extruded.

A pillow-basalt breccia, which overlies most of the Littlefield Rhyolite, consists of pyroclastic and flow fragments of basalt as much as 5 ft across and includes at least one minor unbrecciated flow at its base. The matrix of the breccia locally makes up more than half the unit and appears to be largely black and yellowish basaltic glass although some silt is present. The pillows and the shattered, partly altered basaltic glass suggest interaction of basalt flows and water, possibly in a lake. Hagood (1963) identified labradorite and glass, as major constituents, and minor pyroxene (augite and hypersthene) and olivine. The unit is as thick as 400 ft in the south-central part of the study area and pinches out in places in the western part.

The Tims Peak Basalt (Kittleman and others, 1965) overlies the pillow-basalt breccia and forms most of the top of the plateau in the southern part of the study area. The basalt is dark-gray to black, vesicular, and diktytaxitic, and it forms cliffs showing moderately well developed columnar jointing. Hagood (1963) identified labradorite, clinopyroxene, and olivine as major constituents and minor glass and opaque iron oxide. The maximum thickness in the study area is 200 ft.

A unit of white and pale-gray tuff and tuffaceous siltstone, apparently deposited in a lake, overlies part of the Littlefield Rhyolite near the east boundary of the Gold Creek Wilderness Study Area. These lake beds are as much as 250 ft thick in the study area and are continuous with the thicker sequence of lake beds (fig. 1) that Kittleman and others (1965) named the Bully Creek Formation in the Harper area just east of the study area.

Ages of the units described above range from Miocene to presumably early Pliocene. Fossil data suggest that most of the section is late Miocene or older in age (Hagood, 1963; Kittleman and others, 1965). Three radiometric ages from the Dinner Creek Welded Ash-Flow Tuff, as determined by Fiebelkorn and others (1983), suggest that the tuff is middle Miocene in age. If these radiometric ages are correct, the age of the basaltic complex (the unnamed igneous complex of Kittleman and others, 1965) is middle Miocene or older, and the overall range for the Hunter Creek Basalt through the Tims Peak Basalt is middle Miocene and possibly younger. The suggestion of Kittleman and others (1965) that the Tims Peak Basalt may be early Pliocene in age is consistent with this interpretation. However, radiometric ages listed by Fiebelkorn and others (1983) for the Littlefield Rhyolite and Tims Peak Basalt are older (early Miocene) than the geologic ages discussed above for these units in the study area. It is likely that the samples of the Littlefield Rhyolite and Tims Peak Basalt that were dated may have been subjected to weak epithermal alteration that altered the initial isotope ratios. Unpublished mapping by Evans in the Tims Peak quadrangle, southeast of the study area, suggests that the Tims Peak Basalt correlates with the Shumuray Ranch Basalt of Kittleman and others (1965), which was dated as middle Miocene in age by Fiebelkorn and others (1983). The age of the Bully Creek Formation is not known, but, on the basis of unpublished mapping by Evans southeast of the study area, it is likely to be older than the Tims Peak Basalt.

Pliocene and Quaternary fanglomerate covers 6 mi^2 of the northern part of the study area, extends from the Malheur River to an elevation of 4,200 ft, and is as much as 200 ft thick.

Most of the Holocene landslide deposits, some with areas of as much as 1 mi^2, are associated with the lower contact of the Littlefield Rhyolite and are especially widespread where the rhyolite is thickest in the eastern part of the Gold Creek Wilderness Study Area. Some landslides occur along faults.

Minor Holocene alluvium occurs at the mouth of Gold Creek.

Steep faults that strike north, northwest, and northeast in the study area cut flat-lying and gently dipping units that dip generally northward toward the Malheur River. Vertical displacements are as much as 500 ft. The steep north-striking faults near the east boundary of the Gold Creek Wilderness Study Area may be part of a major fault zone.

Geochemical Studies

The U.S. Geological Survey collected 42 minus-80-mesh stream-sediment samples, 37 concentrate samples panned from stream sediments, 69 rock samples, and 1 hot-spring water sample from the Gold Creek and Sperry Creek Wilderness Study Areas in 1988. The stream-sediment samples reflect bedrock geochemistry and can indicate areas of mineralization. Nonmagnetic heavy-mineral concentrate prepared from a panned concentrate may be useful for detecting minerals associated with mineralization and alteration and is more likely to reveal small or poorly exposed mineralized areas.

All of the samples were analyzed for 35 elements by a six-step semiquantitative emission spectrographic method described by Crock and others (1987). The nonmagnetic heavy-mineral concentrates were also analyzed for platinum and palladium. The stream-sediment and rock samples were analyzed for mercury by an atomic absorption method, for antimony, arsenic, bismuth, cadmium, and zinc by an inductively coupled argon plasma–atomic absorption method described in Crock and others (1987), and for gold by a graphite-furnace atomic absorption method described by Meier (1980). Because the graphite-furnace method does not decompose the silicate minerals in the sample, the gold values obtained are assumed to be due to mineralization and not to background levels of gold in the sample. The stream-sediment samples were analyzed for uranium by the Centanni ultraviolet fluorescence method described by O'Leary and Meier (1986, p. 42-44). Four nonmagnetic heavy-mineral-concentrate samples yielding high tin and beryllium concentration were analyzed for fluorine by an ion-selective electrode method described by O'Leary and Meier (1986, p. 21–23).

The thresholds for anomalous concentrations of elements in rock and stream-sediment samples were calculated at two to three times the arithmetic means of element concentrations in local basalts. When the mode was below the lower level of detection for an element, the lower level of detection was assigned as threshold value. The thresholds for anomalous values of elements in nonmagnetic heavy-mineral concentrates were chosen from previous experience with this sample medium.

Gray and others (1983) and Bukofski and others (1984) reported silver and arsenic anomalies from Simmons Gulch in the northeastern part of the Gold Creek Wilderness Study Area and silver, lead, and copper anomalies from Spring Creek in the northwestern part of the Gold Creek Wilderness Study Area (fig. 2). Those geochemical anomalies and the U.S. Geological Survey samples having anomalous elements in this study suggest that the northern part of the Gold Creek Wilderness Study Area, including the Simmons Gulch and Spring Creek areas, and the eastern part of the Sperry Creek Wilderness Study Area were subjected to hot-spring-type epithermal mineralization. The area of most intense mineralization is indicated by ore-related minerals in the concentrate samples. All of the antimony, arsenic, cadmium, gold, and silver anomalies and the highest boron, cadmium, lead, molybdenum, strontium, tungsten, and zinc anomalies occur in the northern part of the Gold Creek Wilderness Study Area (Malcolm and others, 1990). This is also the area in which quartz and calcite veins are present. Gold was detected (0.002-0.1 ppm) in 13 rock samples from this area.

Silica carbonate sinter is being deposited at a present-day hot spring area along the north boundary of the Gold Creek Wilderness Study Area. The highest concentrations of mercury (more than 36 ppm), arsenic (7,000 ppm), antimony (370 ppm), tungsten (50 ppm), strontium (more than 5,000 ppm), and beryllium (10 ppm) from samples of sinter and black mud at the springs are anomalous. Some of these samples contain as much as 0.002 ppm gold. Cinnabar was identified in a concentrate sample collected from the hot spring; this sample also contains 4 percent fluorine, which suggests the presence of fluorite. The mineralization associated with this hot spring is similar to that which produced the silicification and geochemical anomalies in the northern part of the Gold Creek Wilderness Study Area.

About 0.3 mi south of and 400 ft above the hot spring area, a vertical northwest-striking, 2- to 3-ft-thick hydrothermally brecciated and hydrothermally recemented quartz vein cuts through basalt for at least 0.3 mi. Rock samples show anomalous values of gold as high as 0.045 ppm in the quartz and 0.1 ppm in nearby basalt. (Greater values were found in samples taken in this area by the U.S. Bureau of Mines.) The highest values for silver (3 ppm), mercury (more than 36 ppm), molybdenum (1,000 ppm), arsenic (48 ppm) and antimony (57 ppm) are also anomalous in these rocks. Opal, chalcedony and crystalline quartz were seen in stream gravels and as thin veins in basalt at 15 sites across the northern part of the study area. Galena, cinnabar, barite, and celestite were identified in the panned concentrates from the area of Gold Creek. Molybdenite was identified in panned concentrates from tributaries of lower Simmons Gulch. No native gold was seen during microscopic examination of the panned concentrates, but gold was detected in two stream-sediment samples (0.09 and 0.006 ppm) from small tributaries of lower Simmons Gulch (secs. 11 and 12, T. 21 S., R. 40 E.). The panned concentrate from the tributary yielding 0.006 ppm gold also contains 5 ppm silver, 3,000 ppm molybdenum, 50 ppm beryllium, and 150 ppm tin.

Shotgun shells were noted in the study area, and lead fragments were seen in one concentrate. Therefore, some of the lead and possibly some associated antimony may be due to this contaminant. However, galena that was identified in one panned concentrate and antimony anomalies in rock samples demonstrate that lead and antimony are also clearly related to the epithermal mineralization.

Anomalous beryllium and tin concentrations in many of the panned concentrates appear to come from the Littlefield Rhyolite. Anomalous thorium, yttrium, and lanthanum concentrations also occur in association with the Littlefield Rhyolite in the Simmons Gulch area. Four panned concentrate samples that have relatively high beryllium (10 to 30 ppm) and tin (700 to 1,500 ppm) values were analyzed for fluorine, an element usually associated with beryllium and uranium in fluorite-related beryllium deposits (Griffitts, 1982). The fluorine values range from 1,000 to 2,500 ppm, which are one to three times the average fluorine concentration in most rhyolites and, therefore, are not considered anomalous. Because fluorine concentrations in the panned-concentrate samples and uranium concentrations in all the stream-sediment samples are not anomalous, economic beryllium-fluorine-uranium deposits are unlikely in the study area. Rhyolite-hosted tin deposits (Reed and others, 1986) occur as cassiterite in discontinuous veinlets in rhyolite flow or dome complexes and in placers derived from them, and they may have associated fluorine minerals (fluorite and topaz). Although a rhyolite dome may be present in the southeastern part of the Gold Creek Wilderness Study Area, the scattered grains of beryllium-, lanthanum-, tin-, thorium-, and yttrium-bearing minerals in the Littlefield Rhyolite are the most likely sources of these anomalies, and ore-grade concentrations of these minerals are unlikely in the study area.

Anomalous concentrations of nickel, chromium, vanadium, and manganese in many of the panned concentrates are probably derived from isomorphous substitution of these elements in mafic minerals weathered from basalt. Mafic minerals make up as much as 90 percent of some panned concentrates after the initial magnetic separation. Additional removal of mafic minerals was not attempted because of the small quantity of sample remaining after the initial magnetic separation. Nickel, chromium, and vanadium concentrations correlate well with one another and probably come from a single source, the basalt in the study area. Manganese anomalies are more widespread, and some are related to the epithermal mineralization. For example, one sample of calcite-vein material from basalt in the Gold Creek drainage contains more than 5,000 ppm manganese. Ore-grade chromium, nickel, vanadium, or manganese deposits are not likely in the geologic environment of the study area.

Geophysical Studies

An aeromagnetic survey that includes the Gold Creek and Sperry Creek Wilderness 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. The final residual map was drafted at a scale of 1:125,000.

Additional aeromagnetic data are available in the atlas of the Boise quadrangle (scale 1:500,000) published for the Department of Energy (geoMetrics, Inc., 1979). These data were collected during east-west helicopter flights at an average height of 400 ft above ground and a profile spacing of 3 mi. Two of these profiles cross the wilderness study area.

Variations in the Earth's magnetic field on an aeromagnetic residual map are usually caused by variations in the amounts of magnetic minerals in different rock units; magnetite is 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 at these magnetic latitudes the inclination of the Earth's main magnetic field is relatively steep (68° below the horizontal).

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 more than 2,000 ft above the surface of the ground in this area, a distance great enough to suppress most of the short-wavelength anomalies generated by the rocks at or near the surface. The contoured magnetic map (fig. 3) shows a broad subcircular magnetic high about 4 mi in diameter and about 400 gammas in amplitude that is centered on the southeast boundary of the Gold Creek Wilderness Study Area and extends 3 mi to the northwest, about halfway across the study area. Because of its great width and form, the high represents a causative

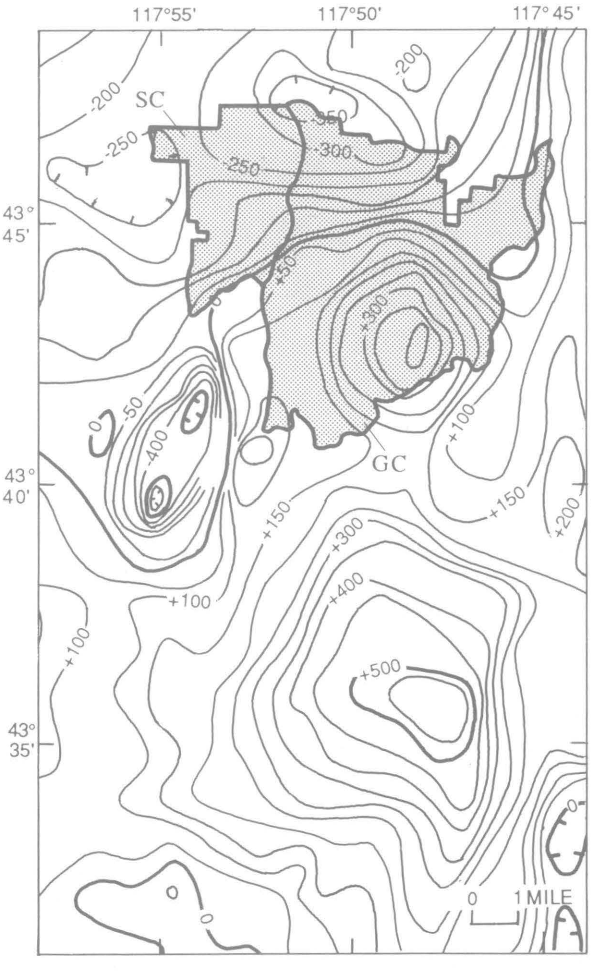


Figure 3. Total-field aeromagnetic anomaly map of region including Gold Creek (GC) and Sperry Creek (SC) Wilderness Study Areas (bold outlines), Malheur County, Oregon. Contour interval 50 gammas; hachures indicate closed areas of lower values.

rock mass at least 5,000 ft thick which may be an intrusion into the basaltic complex (the unnamed igneous complex) that forms the volcanic basement in this area (Kittleman and others, 1967). The causative mass and the magnetic high appear to be terminated on the east by the major north-south fault near the east boundary of the Gold Creek Wilderness Study Area. Geologic relations interpreted by Evans suggest that the aeromagnetic high reflects the buried vent through which the Littlefield Rhyolite of Kittleman and others (1965) was extruded into the study area. The economic potential of this possible rhyolite vent is unknown.

Another major magnetic feature is a distinctive northeast-trending magnetic low, about 6 mi long by 3 mi wide, located 1 mi southwest of the southwest border of the Gold Creek Wilderness Study Area. This anomaly is about 400 gammas in amplitude and correlates well with an uplifted part of the basaltic complex. Two intrusive rhyolite plugs centered within this oval area display intense local magnetic lows having amplitudes of more than 1,500 gammas at an altitude of 300 ft above the ground (geoMetrics, Inc., 1979). The lows are caused by reverse remanent magnetization, certainly in the rhyolite plugs and perhaps also in the uplifted basaltic complex; another reasonable possible cause is 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 these observations have little, if any, economic significance.

A gravity survey of this same region has been described and interpreted in a thesis by Lillie (1977). The average station spacing is about 5 mi, and 15 gravity stations are located within or near the study area. The data are presented as a complete Bouguer gravity anomaly map having a contour interval of 2 milligals and a reduction density of 2.67 grams per cubic centimeter. Over most of the study area the gravity field is relatively featureless. A linear gravity gradient that trends north-south and slopes down to the west along the east border of the Gold Creek Wilderness Study Area is probably associated with the north-south fault on the east side of the study area. Most of this gravity feature is outside the study area and probably has no economic significance, although thermal springs and wells are associated with major north-south faults in the Vale Known Geothermal Resource Area 45 mi to the northeast.

A small gravity low 3 mi in diameter probably extends into the north end of the Sperry Creek Wilderness Study Area. This low may be in part associated with a local small magnetic low. The source of these two associated features is not explained but, on the basis of interpretation of marginal gradients, must be very shallow. These gravity data and features probably do not indicate any resources of economic value.

Aerial gamma-ray spectrometer measurements are available along 3-mi-spaced profiles illustrated in geoMetrics, Inc. (1979). Results indicate that no statistically significant anomalies for uranium, potassium, and thorium occur within the study area. A few uranium anomalies are located outside the study area but within 2 mi of the boundary. Examination of the relation between these anomalies and the geologic map (Kittleman and others, 1967) shows that the anomalies appear to be associated with rocks of the Littlefield Rhyolite of Kittleman and others (1965). The anomalies indicate that these rocks probably contain the largest amounts of uranium, potassium, and thorium in this part of the study area; however, these amounts are probably within the normal ranges for this type of igneous rock and thus do not indicate any resources of economic value.

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

Linear features of every orientation are well expressed on the surface in southeastern Oregon, except in terrains underlain by volcanic rocks. The study area is underlain by volcanic rocks that do not show well-developed linear features at the scale of 1:800,000.

Mineral and Energy Resource Potential

Geologic and geochemical data suggest that part of the north-central part of the Gold Creek Wilderness Study Area has a high mineral resource potential for gold, certainty level B, near the mouth of Gold Creek (fig. 2). This level of potential is suggested by the amount of gold detected in samples from the northwest-striking quartz-vein system and the adjacent basalt wall rock. The certainty level B is assigned because the surficial geochemical data point to only the possibility, rather than the probability, of gold mineralization at depth.

Geologic, geochemical, and geophysical data suggest that the northern part of the Gold Creek Wilderness Study Area and the eastern part of the Sperry Creek Wilderness Study Area have moderate mineral resource potential for gold, silver, and mercury, certainty level B (fig. 2). This estimate of potential is based on the occurrences of these three metals in anomalous concentrations in the rock, stream-sediment, and panned-concentrate samples from the study area and their association with several other elements commonly associated with hot-spring epithermal deposits. These occurrences, and the northwest-striking quartz-vein system, may be related to present and past hot springs along the north boundary of the Gold Creek Wilderness Study Area (fig. 2). The certainty level B is assigned because it seems likely that the hot-spring system results from deeply circulating meteoric waters in a complex fault zone along the Malheur River canyon just north of the study area (Evans, unpub. mapping, 1989) and because it is not clear that economic gold, silver, and mercury deposits occur at depth.

Fouch (1983) estimated that the oil and gas resource potential of the study area is zero to low. Miller (1989) reported possible oil slicks at the hot springs, but these can be explained as contamination from spillage of petroleum products on the nearby highway. The likelihood of occurrences of oil and gas within the study area is low to remote. Therefore, for the purpose of this report, the entire study area is considered to have low energy resource potential for oil and gas, certainty level B.

A small area along the north boundary of the Gold Creek Wilderness Study Area has a low resource potential for geothermal energy, certainty level B (fig. 2). Measurements by the U.S. Bureau of Mines (Miller, 1989) indicate that the water temperature in four orifices exceeds 150 °F and that the combined flow rate is about 40 gallons per minute. Development could increase the flow rate or energy production. The likelihood of production of enough geothermal energy to constitute a resource is low, although the available information only suggests this level of resource potential.

REFERENCES CITED

Benjamin, D.A., and Gale, George, 1984, MLA costing procedures for classification of mineral resources: U.S. Bureau of Mines, Western Field Operations Center, Spokane, Wash., Open-File Report, 60 p.; includes computer program.

Beikman H.M., Hinkle, M.E., Frieders, Twila, Marcus, S.M., and Edward, J.R.,1983, Mineral surveys by the Geological Survey and Bureau of Mines of Bureau of Land Management wilderness study areas: U.S. Geological Survey Circular 901, 28 p.

Boler, F.M., 1978, Aeromagnetic measurements, magnetic source depths, and the Curie point isotherm in the Vale–Owyhee, Oregon, geothermal area: Corvallis, Oregon State University M.S. thesis, 104 p.

Bukofski, J.F., Lovell, J.S., and Meyer, W.T., 1984, Mineral resource assessment through geochemical studies of heavy-mineral concentrates from wilderness study areas in the Burns, Prineville, and Vale districts, southeastern Oregon: Barringer Resources, Inc., prepared for U.S. Bureau of Land Management, Oregon State Office, Portland, 94 p.

Crock, J.G., Briggs, P.H., Jackson, L.L., and Lichte, F.E., 1987, Analytical methods for the analysis of stream sediments and rocks from wilderness study areas: U.S. Geological Survey Open-File Report 87–84, 35 p.

Edmund, R.L., 1989, Annual reference catalog for optics, science, and education: Barington, N.J., Edmund Scientific Company, 163 p.

Emmons, W.H., 1921, Geology of petroleum: New York, McGraw-Hill, 610 p.

Ferns, M.L., 1989, Mining activity and exploration in Oregon, 1988: Oregon Department of Geology and Mining, Oregon Geology, v. 51, no. 2, p. 27–32.

Fiebelkorn, R.B., Walker, G.W., MacLeod, N.S., McKee, E.H., and Smith, J.G., 1983, Index to K-Ar determinations for the State of Oregon: Isochron/West, no. 37, p. 3–60.

Fouch, T.D., 1983, Petroleum potential of wilderness lands in Oregon: U.S. Geological Survey Circular 902–J, 5 p.

geoMetrics, Inc., 1979, Aerial gamma ray and magnetic survey, Idaho Project, Boise [1° by 2°] quadrangle, Oregon/Idaho: Grand Junction, Colo., U.S. Department of Energy, National Uranium Resource Evaluation Program, GJBX–10(80), variously paginated.

Goudarzi, G.H., 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–787, 51 p.

Gray, J.J., Peterson, N.N., Clayton, Janine, Baxter, Gary, 1983, Geology and mineral resources of 18 wilderness study areas, Harney and Malheur Counties, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0–83–2, BLM Contract no. YA–553–CTI–1086, 108 p.

Griffitts, W.R., 1982, Diagnostic features of fluoride-related beryllium deposits, *in* Characteristics of mineral deposit occurrences: U.S. Geological Survey Open-File Report 82–0795, p. 55–59.

Haddock, G.H., 1967, The Dinner Creek Welded Ash-Flow Tuff of the Malheur Gorge area, Malheur County, Oregon: Eugene, University of Oregon Ph.D. dissertation, 111 p.

Hagood, A.R., 1963, Geology of the Monument Peak area, Malheur County, Oregon: Eugene, University of Oregon M.S. thesis, 165p.

Hughes, H.H., 1941, Iceland spar and optical fluorite: U.S. Bureau of Mines Information Circular 6468R, 19 p.

Kittleman, L.R., Green A.R., Haddock, G.H., Hagood, A.R., Johnson, A.M., McMurray, J.M., Russell, R.G., and Weeden, D.A., 1967, Geologic map of the Owyhee region, Malheur County, Oregon: Eugene, University of Oregon, Museum of Natural History Bulletin 8, scale 1:125,000.

Kittleman, L.R., Green, A.R., Hagood, A.R., Johnson, A.M., McMurray, J.M., Russell, R.G., and Weeden, D.A., 1965, Cenozoic stratigraphy of the Owyhee region, southeastern Oregon: Eugene, University of Oregon, Museum of Natural History Bulletin 1, 45 p.

Lillie, R.J., 1977, Subsurface geologic structure of the Vale, Oregon, Known Geothermal Resource Area from the interpretation of seismic reflection and potential field data: Corvallis, Oregon State University M.S. thesis, 52 p.

Malcolm, M.J., Frisken, J.G., and Motooka, J.M., 1990, Analytical results and sample locality map of stream-sediment, heavy-mineral-concentrate, rock, and water samples for the Gold Creek (OR-003-033) and the Sperry Creek (OR-003-035) Wilderness Study Areas, Malheur County, Oregon: U.S. Geological Survey Open-File Report 90–29, 29 p.

McKelvey, V.E., 1972, Mineral resource estimates and public policy: American Scientist, v. 60, p. 32–40.

Meier, A.L., 1980, Flameless atomic absorption determination of gold in geologic materials: Journal of Geochemical Exploration, v. 13, p. 77–85.

Meisinger, A.C., 1989, Diatomite, *in* Mineral commodity summaries: U.S. Bureau of Mines, p. 50–51.

Miller, M.S., 1989, Mineral resources of the Sperry Creek Wilderness Study Area and Gold Creek Wilderness Study Area and addition: U.S. Bureau of Mines Mineral Land Assessment Open-File Report MLA 22–89, 70 p.

Moore, B.N., 1937, Nonmetallic mineral resources of eastern Oregon: U.S. Geological Survey Bulletin 875, 180 p.

Norman, James, and Ralston, O.C., 1940, Purification of diatomite by froth flotation: American Institute of Mining and Metallurgical Engineers, Technical Publication 1198, 11 p.

O'Leary, R.M., and Meier, A.L., 1986, Analytical methods used in geochemical exploration, 1984: U.S. Geological Survey Circular 948, 48 p.

Ramp, Len, 1988, Exploration and mining activity in Oregon, 1987; Oregon State Department of Geology and Mineral Industries, Oregon Geology, v. 50, no. 4., p. 39–44.

Reed, B.L., Duffield, Wendell, Ludington, S.D., Maxwell, C.H., and Richter, D.H., 1986, Descriptive model of rhyolite-hosted Sn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 168.

Subramanian, R.V., Wang, T.J.W., and Austin, H.F., 1977, Reinforcement of polymers by basalt fibers: Society for the Advancement of Material and Process Engineering, Quarterly, v. 8, no. 4, 10 p.

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, 5 p.

Walker, G.W., 1977, Geologic map of Oregon east of the 121st Meridian: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–902, scale 1:500,000.

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 →

<table>
<tr><th>A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td rowspan="4">U/A
UNKNOWN POTENTIAL</td><td>H/B
HIGH POTENTIAL</td><td>H/C
HIGH POTENTIAL</td><td>H/D
HIGH POTENTIAL</td></tr>
<tr><td>M/B
MODERATE POTENTIAL</td><td>M/C
MODERATE POTENTIAL</td><td>M/D
MODERATE POTENTIAL</td></tr>
<tr><td rowspan="2">L/B
LOW POTENTIAL</td><td rowspan="2">L/C
LOW POTENTIAL</td><td>L/D
LOW POTENTIAL</td></tr>
<tr><td>N/D
NO POTENTIAL</td></tr>
</table>

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.
Taylor, R.B., Stoneman, R.J., and Marsh, S.P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40-42.
Goudarzi, G.H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84-0787, p. 7, 8.

RESOURCE/RESERVE CLASSIFICATION

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

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

GEOLOGIC TIME CHART

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

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

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

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