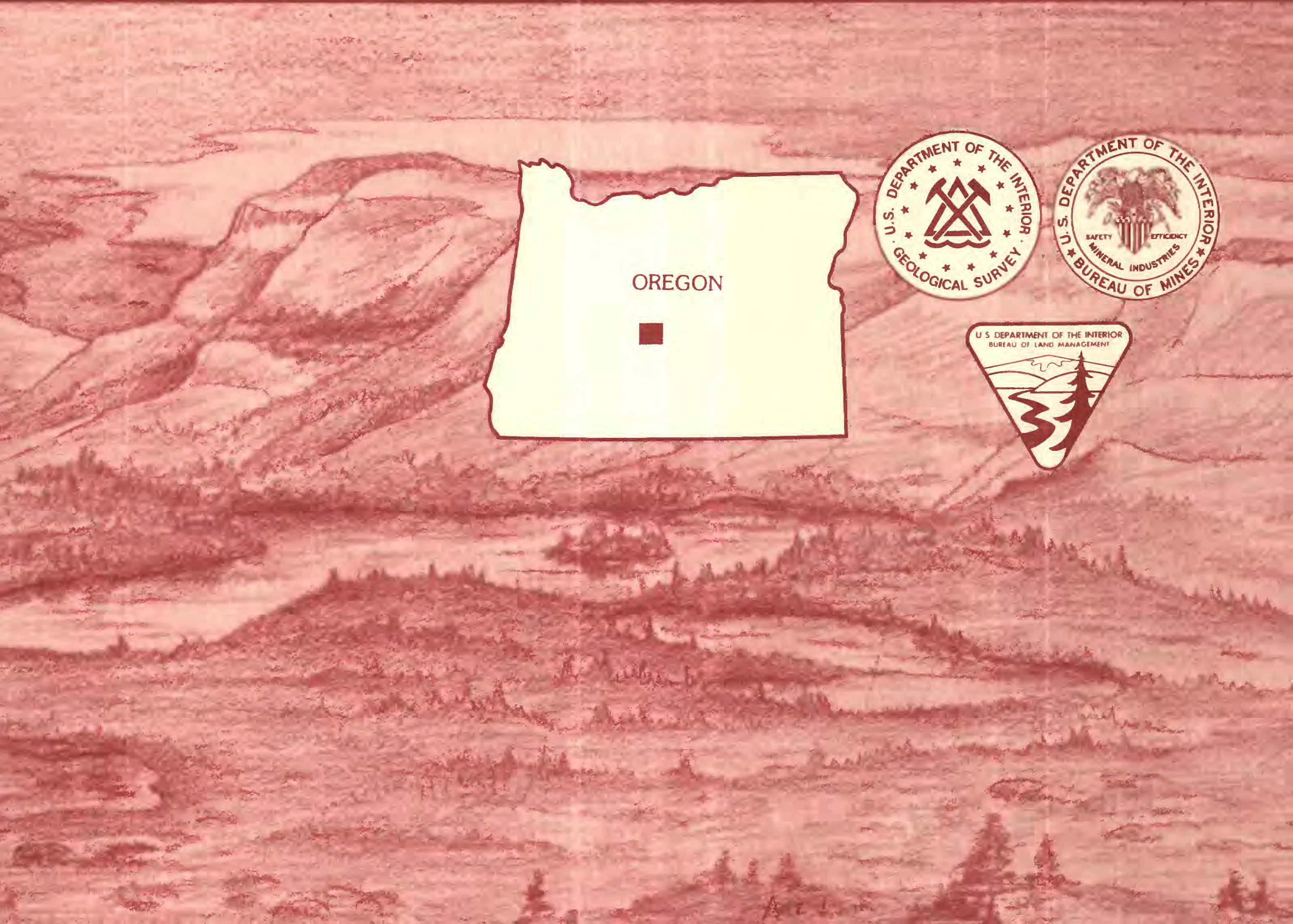
Mineral Resources of the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas, Lake County, Oregon

U.S. GEOLOGICAL SURVEY BULLETIN 1738–A



Chapter A

Mineral Resources of the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas, Lake County, Oregon

By WILLIAM J. KEITH, HARLEY D. KING, and
MARK E. GETTINGS
U.S. Geological Survey

FREDRICK L. JOHNSON
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1738

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
SOUTH-CENTRAL OREGON

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1988

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

Library of Congress Cataloging-in-Publication Data

Mineral resources of the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas, Lake County, Oregon.

(U.S. Geological Survey bulletin ; 1738-A)
Supt. of Docs. no. : I 19.3:1738-A
Bibliography: p.
1. Mines and mineral resources—Oregon—Devil's Garden Lava Bed Wilderness. 2. Mines and mineral resources—Oregon—Squaw Ridge Lava Bed Wilderness. 3. Mines and mineral resources—Oregon—Four Craters Lava Bed Wilderness. 4. Devil's Garden Lava Bed Wilderness. (Or.) 5. Squaw Ridge Lava Bed Wilderness (Or.) 6. Four Craters Lava Bed Wilderness (Or.)
I. Keith, William J., 1933- . II. Series.
QE75.B9 no. 1738-A 557.3 s 88-600094
[TN24.07] [553'.09795'93]

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 parts of the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas (OR-001-002, OR-001-003, OR-001-022 respectively), Lake County, Oregon.

CONTENTS

FIGURES

Mineral Resources of the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas, Lake County, Oregon

By William J. Keith, Harley D. King, *and* Mark E. Gettings
U.S. Geological Survey

Fredrick L. Johnson
U.S. Bureau of Mines

SUMMARY

Abstract

The Devil's Garden Lava Bed (OR-001-002), Squaw Ridge Lava Bed (OR-001-003), and Four Craters Lava Bed (OR-001-022) Wilderness Study Areas are located in the southwestern part of the High Lava Plains physiographic province, northwestern Lake County, Oregon. At the request of the U.S. Bureau of Land Management, 28,160 acres of the 29,680-acre Devil's Garden Lava Bed, 21,040 acres of the 28,660-acre Squaw Ridge Lava Bed, and 9,100 acres of the 12,600-acre Four Craters Lava Bed Wilderness Study Areas were studied. In this report, the areas investigated are referred to as "the wilderness study areas," or simply "the study areas." Geologic, 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 mineral resources (known) and mineral resource potential (undiscovered) of the study areas. No resources were identified in the study areas, but the results of these surveys indicate an area of low potential for perlite resources in the Devil's Garden Lava Bed Wilderness Study Area. The Devil's Garden Lava Bed and the north half of the Squaw Ridge Lava Bed Wilderness Study Areas also have low potential for slab-lava (building stone) resources. All three study areas have low potential for low-temperature (less than 194 °F) geothermal resources and for oil and gas resources.

Character and Setting

The study areas are located in the southwestern part of the High Lava Plains physiographic province, northwest Lake County, Oregon. They are north to northwest of Christmas Valley and east of Fort Rock (fig. 1). Relief is moderate; elevations range from 4,325 ft at the edge of Four Craters Lava Bed to a high of 5,612 ft in the center of the Squaw Ridge Lava Bed. The basaltic lava flows underlying the study areas are of Pleistocene or Holocene age (see appendixes for geologic time chart), these in turn overlie Pliocene and (or) Pleistocene lava flows and cinder cones.

Identified Resources

There are no metallic or nonmetallic reserves or identified resources in the three study areas. There are a few small, scattered occurrences of good quality slab lava in the Devil's Garden Lava Bed and Squaw Ridge Lava Bed Wilderness Study Areas, but most of the accessible material has been removed. Slab lava in the Four Craters study area is generally of poor quality. Cinder and natural aggregate also occur in all three study areas, but sites are far from prospective markets.

Mining claim records show that there are no active mining claims in or adjacent to the three study areas and that past mining activity has been minimal. Several claims for borax were located at the turn of the century just outside the Four Craters Lava Bed Wilderness Study Area; four uranium claims were staked during the mid-1950's in Devil's Garden Lava Bed Wilderness Study Area; and six building stone claims were staked in the early 1970's in the Squaw Ridge Lava Bed Wilderness Study Area.

Mineral Resource Potential

A small area in the southern part of the Devil's Garden Lava Bed Wilderness Study Area has low potential for perlite resources, and the Devil's Garden Lava Bed and the north half of the Squaw Ridge Lava Bed Wilderness Study Areas have low potential for slab lava. All three study areas have low potential for low-temperature (less than 194 °F) geothermal resources and oil and gas resources.

Devil's Garden Lava Bed Wilderness Study Area

A small area containing low-quality perlite occurs near the southern part of Devil's Garden Lava Bed Wilderness Study Area. More recent lava beds may cover part or most of the deposit. The area, which lies near the base of Cougar Mountain, is considered to have low potential for perlite resources (fig. 2) of commercial quality, although development is unlikely due to the lava cap.

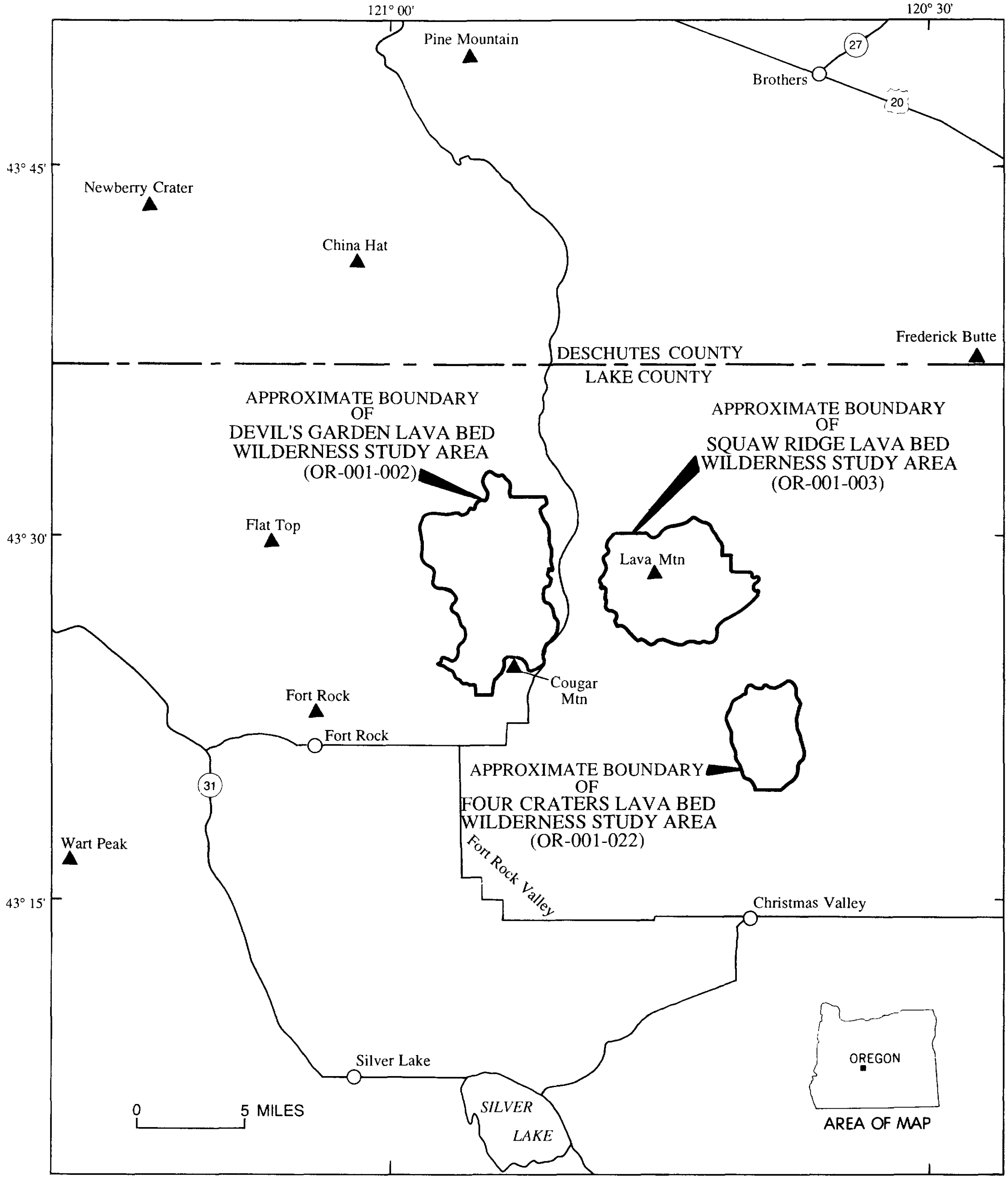


Figure 1. Index map showing location of the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas, Lake County, Oregon.

The study area also has low potential for slab-lava resources, but development is also unlikely due to low quality, poor access, and an abundance of higher quality rock from other areas.

Holocene volcanism has occurred in the study area, and the area also has relatively high heat flow, suggesting low potential for low-temperature (less than 194 °F) geothermal resources.

This study area also has low potential for oil and gas resources. Source beds may underlie or interbed with the older lava flows in this area and could contain oil and gas.

Squaw Ridge Lava Bed Wilderness Study Area

The north half of the Squaw Ridge Lava Bed Wilderness Study Area has low potential for slab-lava resources. However, these resources will probably not be developed due to low quality, poor access, and an abundance of higher quality rock from other areas.

Holocene volcanism has occurred in the Squaw Ridge Lava Bed Wilderness Study Area (fig. 3), and the area also shows relatively high heat flow suggesting low potential for low-temperature (less than 194 °F) geothermal energy resources.

This study area also has low potential for oil and gas resources. Source beds may underlie or interbed with the older lava flows in this area and could contain oil and gas.

Four Craters Lava Bed Wilderness Study Area

Holocene volcanism has occurred in the Four Craters Lava Bed Wilderness Study Area (fig. 3), and the area also shows relatively high heat flow suggesting low potential for low-temperature (less than 194 °F) geothermal energy resources.

This study area also has low potential for oil and gas resources. Source beds may underlie or interbed with the older lava flows in this area and could contain oil and gas.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management and is a joint 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 the system described by U.S. Bureau of Mines and U.S. Geological Survey (1980). Studies by the U.S. Geological Survey are designed to provide a reasonable scientific basis for assessing the potential for undiscovered mineral resources by determining geologic units and structures, possible environments of mineral deposition, presence of geochemical and geophysical anomalies, and applicable ore-deposit models. Mineral assessment methodology and terminology as they apply to these surveys were discussed by Goudarzi (1984). See the appendixes for definitions 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, 28,160 acres of the 29,680-acre Devil's Garden Lava Bed, 21,040 acres of the 28,660-acre Squaw Ridge Lava bed, and 9,100 acres of the 12,600-acre Four Craters Lava Bed Wilderness Study Areas in northwest Lake County, Oregon (fig. 1), were studied. These study areas lie approximately 50 mi southeast of Bend, Oregon and are part of the High Lava Plains physiographic province. In this report, the areas studied are referred to as "the wilderness study areas," or simply "the study areas." The study areas are underlain by sparsely vegetated, basaltic lava flows that have flowed over and around older surface features. The study areas are accessible on all sides by unmaintained jeep trails. The interiors are accessible only by helicopter or on foot except for the Devil's Garden Lava Bed Wilderness Study Area which has several jeep trails scattered throughout the north half of the area. Elevations range from 4,325 ft at the east edge of the Four Craters Lava Bed Wilderness Study Area to 5,612 ft on top of Lava Mountain in the central part of the Squaw Ridge Lava Bed Wilderness Study Area.

Previous and Present Investigations

A geologic map of the study areas, prepared by the U.S. Geological Survey in 1986 (figs. 2 and 3), provided a base for the interpretation of geochemical, geophysical, remote sensing, and mining claim data. The geologic map is adapted from the reconnaissance geologic map of the east half of the Crescent quadrangle, Lake, Deschutes, and Crook Counties, Oregon, by Walker and others (1967). Studies by Engineers International, Inc. (1980), MacLeod and others (1976), and Wilson and Emmons (1985) also provided geologic data for this report.

Geochemical data were obtained from analyses of rock-chip samples collected by the U.S. Geological Survey (unpub. data, 1986) and rock-chip, soil, and stream-sediment samples collected by the U.S. Bureau of Land Management (Durga Rimal, unpub. data, 1983).

Geophysical data consist of two aeromagnetic surveys that, when combined, cover all three study areas (U.S. Geological Survey, 1972, 1984), and a third study of radiometric and aeromagnetic data for the National Uranium Resources Evaluation (High Life Helicopters-QEB, 1981).

The U.S. Bureau of Mines reviewed all available information on geology, mining, and exploration in the

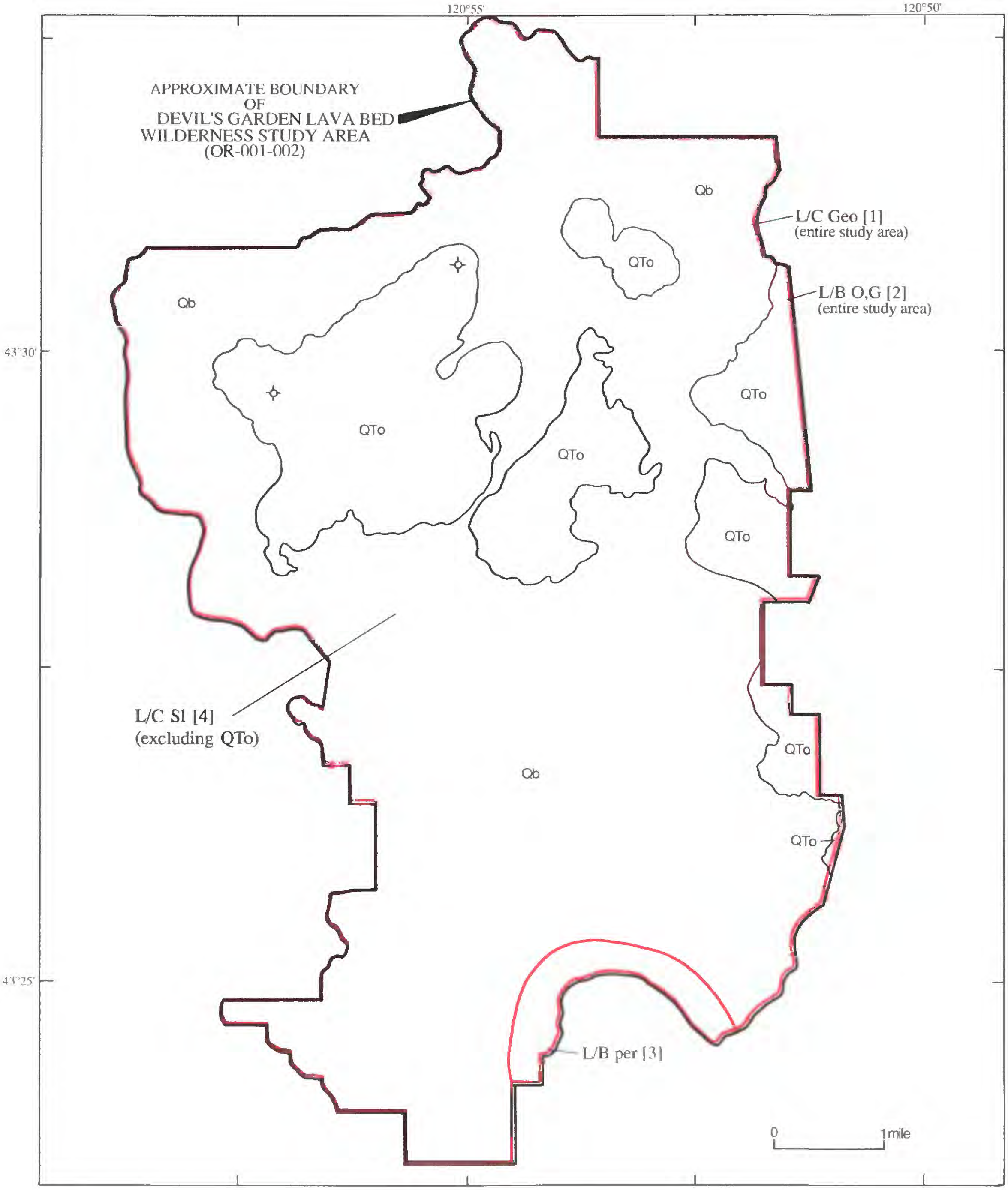


Figure 2. Map showing resource potential and generalized geology of the Devil's Garden Lava Bed Wilderness Study Area, Lake County, Oregon.

area, including county mining claim records, prior to field work. The field investigation, conducted during the spring of 1986, included driving all roads in and near the study areas and making numerous foot traverses. All areas described by Engineers International, Inc. (1980) as having "high"potential for slab lava were investigated to determine quality and tonnage.

EXPLANATION

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

Commodities

Geo	Geothermal
O,G	Oil and gas
Sl	Slab lava
per	Perlite

[ ] Type of deposit or occurrence

1	Geothermal water
2	Source beds and (or) traps
3	Silicic glass
4	Surficial deposits

Geologic map units

Qb Basalt (Holocene or Pleistocene)--Pahoehoe and aa type basalt flows, agglutinates, and cinder cones

QTo Older lava flows (Pleistocene and (or) Pliocene)--Older basalt, andesite, dacite, and rhyolite flows and domes. Locally includes tuffaceous sediments and basin-fill material

——— Contact

✧ Cinder cone

Figure 2. Continued.

APPRAISAL OF IDENTIFIED RESOURCES

By Fredrick L. Johnson
U.S. Bureau of Mines

Mines and Prospects, Mining Claims, and Leases

A search of Lake County and Bureau of Land Management mining records revealed that no active claims and only a few historical claims were located in the study areas. Four claims were located for uranium during the mid-1950's in the Devil's Garden Lava Bed Wilderness Study Area. Six claims, located during the early 1970's in the west-central part of the Squaw Ridge Lava Bed Wilderness Study Area, were probably for slab-lava building stone. Apparently no claims were ever located in the Four Craters Lava Bed Wilderness Study Area, but several claims for borax were located at the turn of the century just southeast of the area.

The only working in the study areas was a small pit at the base of a cinder cone near the northwest boundary of Four Craters Lava Bed Wilderness Study Area. Just a few cubic yards of cinder had been removed.

At the time of the study, the nearest mining activity was about 2 mi southwest of Christmas Valley (fig. 1) where diatomite was being mined and processed.

Reserves and Identified Resources

There are no mineral reserves or identified resources in the three areas studied. However, slab lava, used as building stone, is present. Some slab lava in the Devil's Garden Lava Bed and Squaw Ridge Lava Bed Wilderness Study Areas is of good quality, but occurrences are widely scattered and access poor. At those areas most accessible, most usable material has been removed. The Four Craters Lava Bed Wilderness Study Area, principally underlain by aa lava (lava flows typified by a rough, jagged, spinose, clinkery surface), also contains some slab lava, but the material is of poor quality.

In the Bend area, the nearest town of any size, demand for slab lava has dropped significantly since 1980; the local market is currently being met by sources in southeastern Idaho. Wholesale prices (1986) for 3- to 4-in.-thick and 2-in.-thick slab lava were $45 and $60 per ton, respectively (Willamette Greystone Co., oral commun., 1986). Transportation costs, relatively low unit prices, difficult access, and the scattered, sparse distribution of the slab lava make commercial production of this stone unlikely in the foreseeable future.

Cinder and sand and gravel occurrences in the study areas might be suitable for some construction purposes. However, transportation costs to potential markets, a major part of total production costs for these high bulk-low unit value commodities, would far exceed the value. Similar material, abundant elsewhere in central Oregon, is closer to major markets in the region.

Additional information on U.S. Bureau of Mines work in these study areas is available from the Western Field Operations Center, E. 360 Third Avenue, Spokane, WA 99202 and in Johnson (1987).

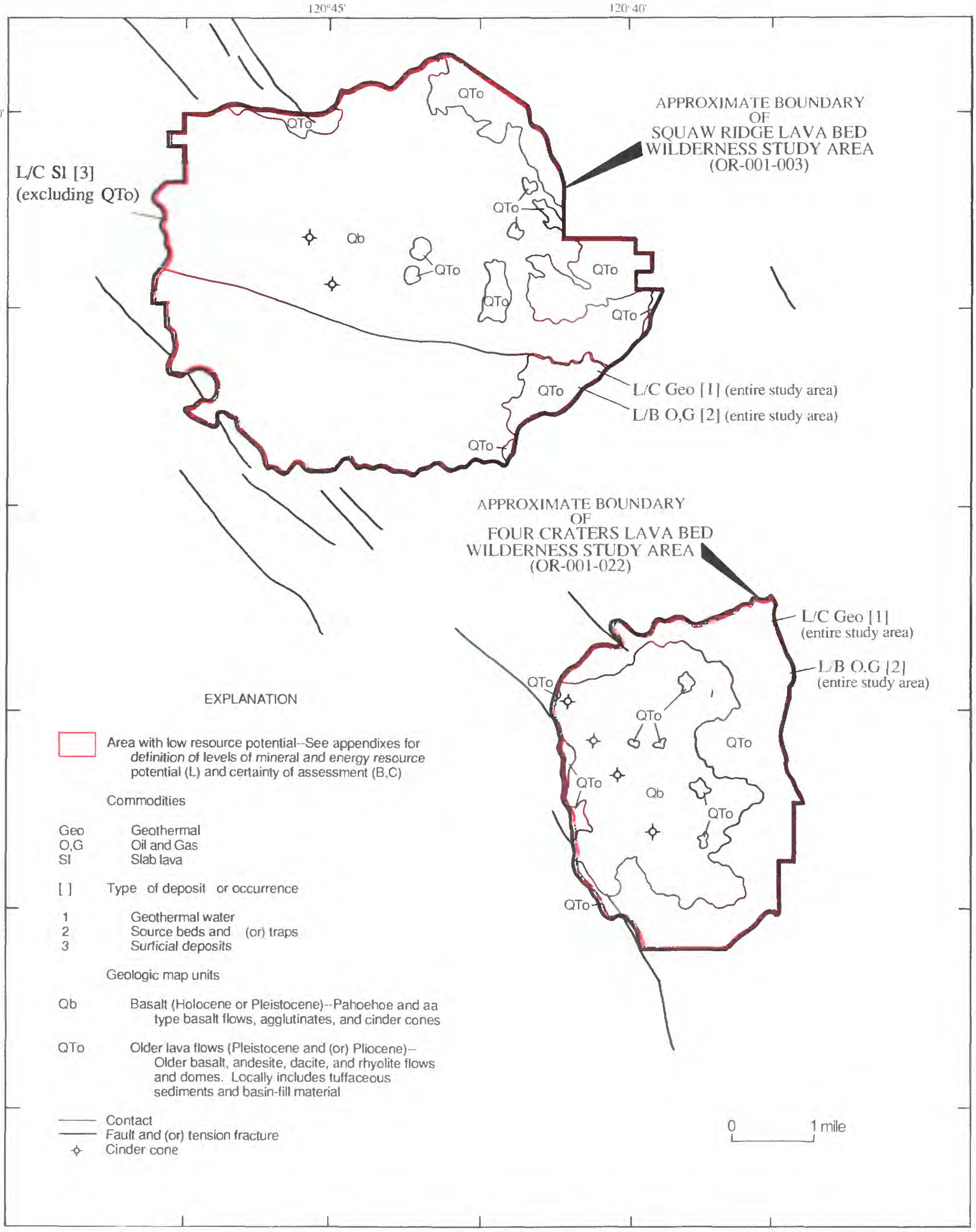


Figure 3. Map showing mineral resource potential and generalized geology of the Squaw Ridge Lava Bed and Four Craters Lava Bed Wilderness Study Areas, Lake County, Oregon.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By William J. Keith, Harley D. King, *and* Mark E. Gettings
U.S. Geological Survey

Geology

Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas are all underlain by Pleistocene or Holocene basalt flows that overlie older (Pliocene to Pleistocene) basaltic to more silicic lavas and palagonitized basaltic ejecta. The younger basalts range from predominantly pahoehoe type in the Devil's Garden area to predominantly aa type in the Four Craters area. The young basalt in the Squaw Ridge area consists largely of aa type with a lesser amount of pahoehoe scattered throughout. The surface of the Devil's Garden area contains many textbook-type examples of pahoehoe-related features such as tumuli, collapse features, and spatter cones. On the northeast edge of the Devils' Garden area, one large lava tube has been found that is over 1,500 ft long and, in places, over 40 ft high (Engineers International, Inc. 1980, p. 86). Features in the Squaw Ridge and Four Craters areas are more typical of aa lavas. These consist of cinder cones and pressure ridges of clinkery blocks. The older lavas include basalt, andesite, dacite, and rhyolite flows as well as dacitic to rhyolitic domes and plugs. The young basalts flowed around older features such as older cinder cones and domes of silicic lava. One of the silicic domes (Cougar Mountain) on the south border of the Devil's Garden Lava Bed Wilderness Study Area (fig. 2) has a potassium-argon age of 4.31 ± 0.34 Ma (MacLeod, Walker, and McKee, 1976, p. 468). Outcrops of impure perlite here probably owe their origin to the hydration of rhyolitic glass by ground water or fresh-water lakes that formerly covered this area.

Structure in the area consists of high-angle faults and tension fractures which trend in a generally northwest direction. Some of the tension fractures are over 30 ft deep and have vertical walls.

Geochemistry

The reconnaissance geochemical study of the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and the Four Craters Lava Bed Wilderness Study Areas included the collection, analysis, and evaluation of 36 rock samples collected from 36 sites in the three study areas. The distribution of the sample sites is as follows: Devil's Garden Lava Bed Wilderness Study area, 19 samples; Squaw Ridge Lava Bed Wilderness Study Area, 8 samples; Four Craters Lava Bed Wilderness Study Area, 9 samples. The sampling was done partly in conjunction with geologic mapping.

Rock samples were used as the only sample medium in this reconnaissance geochemical study. Representative rock samples were taken from outcrops of each rock unit present in the three study areas. Rock that appeared altered or mineralized was looked for but not found. Lack of appropriate streams in the study areas prevented the use of stream sediments or heavy-mineral concentrates. The few streams present drain areas chiefly underlain by eolian deposits, hence sediment associated with them is unlikely to reflect bedrock mineralization. Water from wells is a possible sample medium, since a number of wells are located peripheral to the study areas; however most of the wells are abandoned or inactive, and water samples were rarely available or are of questionable quality.

The rock samples were crushed and pulverized to a grain size of less than 0.007 in. prior to analysis. The samples were analyzed semiquantitatively for 31 elements using direct-current arc emission spectrography (Grimes and Marranzino, 1968). The samples were also analyzed by inductively coupled argon plasma-atomic emission spectroscopy for antimony, arsenic, bismuth, cadmium, and zinc and by atomic absorption for gold and mercury (methods described in Crock and others, 1987). Analytical data are from M.S. Erickson and others (written commun., 1987).

A value of 70 parts per million (ppm) lead was found in one sample of a rhyolitic flow taken from the north slope of one of the domes in the Devil's Garden Lava Bed Wilderness Study Area. The value is slightly anomalous relative to an average crustal abundance of 20 ppm for felsic igneous rocks (Levinson, 1980). No other elements were found in anomalous concentration in this sample. Therefore, this anomalous concentration of lead is believed to be nonsignificant and does not reflect mineralized rock.

Three samples of flow basalts from the Devil's Garden Lava Bed Wilderness Study Area and one from the Four Craters Lava Bed Wilderness Study Area contained slightly anomalous values for antimony (3-5 ppm), compared to average crustal abundance values of about 1 ppm or less in basalts (Onishi, 1969; Levinson, 1980). The samples are from widely separated sites. The low values and absence of other indications of antimony deposits in the areas suggest that the values represent background values for the basalt flows.

No other elements were found in anomalous concentrations in samples from any of the three study areas.

Geophysics

An aeromagnetic survey of the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed Wilderness Study Areas was flown and compiled in 1972 (U.S. Geological Survey, 1972). Total field magnetic data were collected in analog form along flightlines in an east-west direction spaced at approximately 2-mi intervals at a constant barometric altitude of 9,000 ft. Corrections were applied to the data to compensate for diurnal variations of the Earth's magnetic field. A regional field of 8 nanotesla (nT) per mile in the direction of N. 30° E. was subtracted to yield a residual magnetic anomaly dataset. An aeromagnetic map of the study areas was prepared at a contour interval of 50 nT from the digitized analog data for comparison with geologic and topographic maps. North of lat 43°30', aeromagnetic data are available from another survey (U.S. Geological Survey, 1984) flown along east-west lines spaced approximately 3 mi apart at a constant barometric elevation of 7,500 ft. The southernmost flightline of the survey crosses the northern part of Devil's Garden Lava Bed Wilderness Study Area, and the contour map in the report (U.S. Geological Survey, 1984) was used to examine the continuation of regional magnetic anomalies north of lat 43°30'.

Airborne radiometric and magnetic data are also available for the Crescent quadrangle from the National Uranium Resource Evaluation study (High Life Helicopters-QEB, 1981). Survey lines for this survey were oriented east-west and spaced 6 mi apart at a terrain clearance of approximately 400 ft. Three flight lines from this study cross the study areas. The radiometric profiles did not detect any significant anomalies, and no new information was gained from the magnetic data because of the wide line spacing. The radiometric profiles show that the Tertiary and Quaternary mafic volcanic rocks have a systematically higher gamma-ray emission than the late Quaternary basalt flows, and thus the two rock units are distinguished by the data although neither are anomalous.

The magnetic intensities within and near Devil's Garden Lava Bed Wilderness Study Area have a total range of about 250 nT and form a northwest-trending trough-like magnetic minimum. The anomaly is smooth, does not exhibit any suggestion of shallow magnetization contrasts, and is interpreted as reflecting variations of magnetization and depth to magnetic basement. This does not, however, give any indication of the physical thickness of the lava flows.

A regional magnetic maximum in the form of a northwest-trending ridge about 3.7 mi wide borders the Devil's Garden Lava Bed Wilderness Study Area to the north and extends southeast through the Squaw Ridge Lava Bed Wilderness Study Area. Within the Squaw Ridge Lava Bed Wilderness Study Area, the magnetic field consists of a positive anomaly of about 300 nT amplitude of which approximately 200 nT is closely correlated with the topographic expression of Lava Mountain (fig. 1), and the remaining portion of the anomaly is the regional northwest trending ridge. The magnetic data within and near the Squaw Ridge Lava Bed Wilderness Study Area do not contain any anomalies which are not attributable to topographic effects or regional structural blocks delineated by the mapped fault patterns. A left-lateral offset of 1.2 to 1.9 mi of the magnetic anomaly ridge suggests strike-slip faulting in a northeast-trending area located approximately along the northwest boundary of the Devil's Garden Lava Bed Wilderness Study Area.

The magnetic field within and near the Four Craters Lava Bed Wilderness Study Area consists of a smooth magnetic field gradient, increasing to the southeast. The field increases about 250 nT across the study area, and the gradient suggests that a northeast trending boundary marking an increase in average magnetization to the southeast, occurs near the northwest boundary of the study area. Northwest of this boundary the contours of magnetic intensity are sub-parallel to the mapped faults and form a gradient that increases to the southwest. No other magnetic anomalies were observed in the study area.

D.L. Sawatzky mapped the orientations of linear features for southeastern Oregon from Landsat multispectral scanner images at a scale of 1:800,000 and plotted them on a 1:1,000,000-scale map. Images of the area between long. 120°-121° W. and lat. 43°-44° N. (including the study areas) do not reveal any linear features. This is probably due to the young volcanic cover (D.L. Sawatzky, written commun., 1987).

Mineral and Energy Resources

Except for perlite and slab lava, the potential for mineral and energy resources is the same in all three study areas. The resource potential is discussed separately below to facilitate planning and decision making on each area independently.

Devil's Garden Lava Bed Wilderness Study Area

The Devil's Garden Lava Bed Wilderness Study Area has low potential (certainty level B) for perlite resources in the area under the basalt flows near Cougar Mountain (fig. 2). Impure perlite occurs in numerous small areas near the base on the south side of Cougar Mountain. A small (20 ft^2) exposure located at the base of the north side of Cougar Mountain contains granular perlite similar to that described at the Tucker Hill perlite deposit in southern Lake County, Oregon (Wilson and Emmons, 1985). These occurrences support the conclusion that the perlite might extend under the basalt. Therefore, the area of low resource potential for perlite (fig. 2) includes part of the covering basalt near Cougar Mountain. Although other areas of silicic rock are present in and near the study area, they show no indication of perlite formation and are therefore not included in the area having low resource potential for perlite. The perlite is likely to be relatively impure. Development of presently undiscovered perlite resources is not anticipated due to the poor quality of the materials, the need to strip off the volcanic cover, the distance from markets, and the abundance of better quality perlite from other sources.

The resource potential for slab lava (building stone) is low (certainty level C) in the study area. The bulk of the slab lava is probably of low quality, the access to the material is poor to nonexistent, and there is an abundance of high-quality material from other areas. It is therefore doubtful that slab lava from this area will be developed in the forseeable future.

The study area has low potential (certainty level C) for low-temperature (less than 194 °F) geothermal resources. No thermal springs are known to exist in the study area, and no areas of hydrothermal alteration were found. However, the study area has undergone Holocene volcanism and has relatively high heat flow. Potential for geothermal resources is also somewhat enhanced by the presence of three igenous-related geothermal systems (Newberry Crater, Wart Peak Caldera, and Frederick Butte areas, Smith and Shaw, 1979) within a 50-mi radius of the study area.

The study area also has low potential (certainty level B) for oil and gas resources. There are no known surface occurrences of oil or gas in the study area, nor are there any indications in any of the water wells. However, source beds of older basin material may underlie or be interbedded with the volcanic rocks at depth (Fouch, 1983). The maturation level for oil may have been exceeded in the older basin fill of the study area (Fouch, 1983). In that case, oil would not have been preserved. However, since the thermal history has not been established, the study area has low resource potential for oil as well as gas.

Squaw Ridge Lava Bed Wilderness Study Area

The north half of the Squaw Ridge Lava Bed Wilderness Study Area has low potential (certainty level C) for slab lava (building stone). The bulk of the slab lava is probably of low quality, the access to the material is poor to nonexistent, and there is an abundance of high-quality material from other areas. This makes it doubtful that slab lava from this area will be developed in the forseeable future.

The study also has low potential (certainty level C) for low-temperature (less than 194 °F) geothermal resources. No thermal springs are known to exist in the study area, and no areas of hydrothermal alteration were found. However, the study area has undergone Holocene volcanism and has relatively high heat flow. Potential for geothermal resources is also somewhat enhanced by the presence of three igenous-related geothermal systems (Newberry Crater, Wart Peak Caldera, and Frederick Butte areas, Smith and Shaw, 1979) within a 50-mi radius of the study area.

The study area has low potential (certainty level B) for oil and gas resources. There are no known surface occurrences of oil or gas in the study area, nor are there any indications in any of the water wells. However, source beds of older basin material may underlie or be interbedded with the volcanic rocks at depth (Fouch, 1983). The maturation level for oil may have been exceeded in the older basin fill of the study area (Fouch, 1983). In that case, oil would not have been preserved. However, since the thermal history has not been established, the study area has low resource potential for oil as well as gas.

Four Craters Lava Bed Wilderness Study Area

The Four Craters Lava Bed Wilderness Study Area has low potential (certainty level C) for low-temperature (less than 194 °F) geothermal resources. No thermal springs are known to exist in the study area, and no areas of hydrothermal alteration were found. However, the study area has undergone Holocene volcanism and has relatively high heat flow. Potential for geothermal resources is also somewhat enhanced by the presence of three igenous-related geothermal systems (Newberry Crater, Wart Peak Caldera, and Frederick Butte areas, Smith and Shaw, 1979) within a 50-mi radius of the study area.

The study area also has low potential (certainty level B) for oil and gas resources. There are no known surface occurrences of oil or gas in the study area, nor are there any indications in any of the water wells. However, source beds of older basin material may underlie or be interbedded with the volcanic rocks at depth (Fouch, 1983). The maturation level for oil may have been exceeded in the older basin fill of the study area (Fouch, 1983). In that case, oil would not have been preserved. However, since the thermal history has not been established, the study area has low resource potential for oil as well as gas.

REFERENCES CITED

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

Engineers International, Inc., 1980, Geological investigations and mineral inventory of Devil's Garden, Four Craters, and Squaw Ridge in Lake County, Oregon: Report prepared for the U.S. Bureau of Land Management, contract no. OR-910-CT9-16, 135 p.

Fouch, T.D., 1983, Petroleum potential of wilderness lands in Oregon, *in* Miller, B.M., ed., Petroleum potential of wilderness lands in the western United States: U.S. Geological Survey Circular 902, p. J1-J5.

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.

Grimes, D.J., and Marranzino, A.P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.

High Life Helicopters-QEB, 1981, Airborne gamma-ray spectrometer and magnetometer survey, Crescent quadrangle (Oregon), final report: U.S. Department of Energy Grand Junction Office [Report] GJBX 240-81, v. 2, scale 1:500,000.

Johnson, F.L., 1987, Mineral resources of the Devil's Garden Lava Bed, Squaw Ridge Lava Bed, and Four Craters Lava Bed study areas, Lake County OR: U.S. Bureau of Mines Open-File Report MLA 37-87, 10 p.

Levinson, A.A., 1980, Introduction to exploration geochemistry, second edition, the 1980 supplement: Ltd. Wilmette, Ill., Applied Publishing.

MacLeod, N.S., Walker, G.W., and McKee, E.H., 1976, Geothermal significance of the eastward increase in age of late Cenezoic rhyolitic domes in southeastern Oregon: United Nations Symposium on Development and Use of Geothermal Resources, v. 1.

Onishi, H., 1969, Antimony *in* Wedepohl, K.H., ed., Handbook of geochemistry, vol. III: Berlin, Heidelberg, New York, Springer-Verlag, p. 51 B-M, O.

Smith, R.L., and Shaw, H.R., 1979, Igneous-related geothermal systems, *in* Muffler, L.J.P., ed., Assessment of geothermal resources of the United States-1978: U.S. Geological Survey Circular 790, 163p.

Walker, G.W., Peterson, N.V., and Greene, R.C., 1967, Reconnaissance geologic map of the east half of the Crescent quadrangle, Lake, Deschutes, and Crook Counties, Oregon: U.S. Geological Survey Miscellaneous Investigations Map I-493, scale 1:250,000.

Wilson, J.L., and Emmons, D.L., 1985, Tucker Hill perlite deposit, Lake County Oregon: Mining Engineering, vol. 37, no. 11, p. 1301-1308.

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.

U.S. Geological Survey, 1972, Aeromagnetic map of the Klamath Falls and part of the Crescent 1° x 2° quadrangles, Oregon: U.S. Geological Survey Open-File Report, scale 1:250,000.

U.S. Geological Survey, 1984, Aeromagnetic map of east-central Oregon: U.S. Geological Survey Open-File Report 84-512, scale 1:250,000.

APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

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

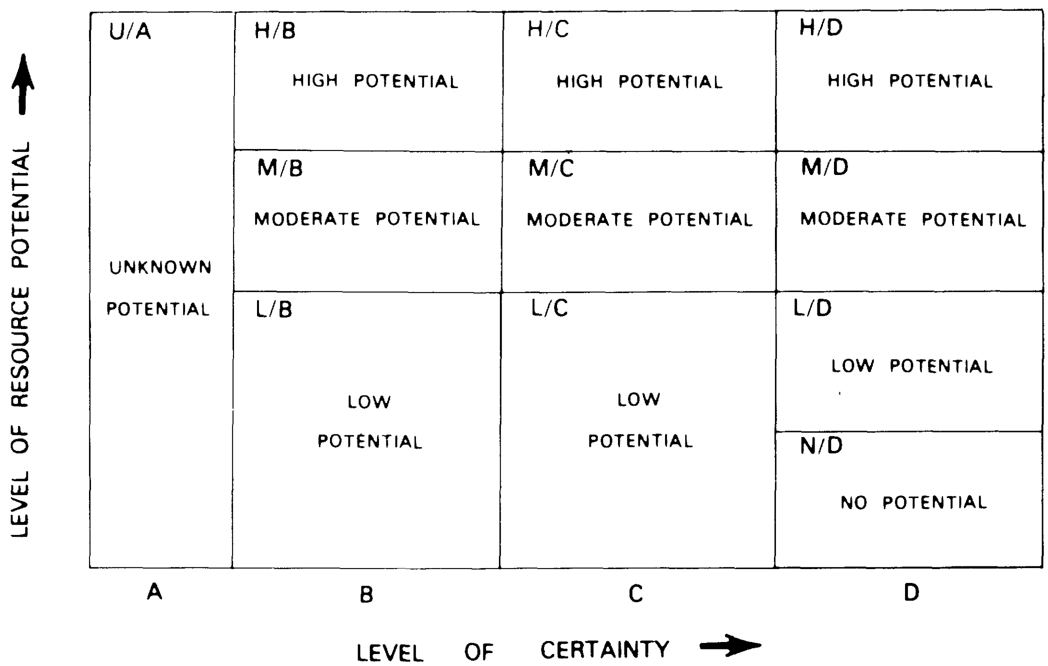
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate reasonable likelihood of resource accumulation, and (or) where an application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

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

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

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

Levels of Certainty



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

Abstracted with minor modifications from:

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 U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, p. 5.

GEOLOGIC TIME CHART

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

EON	ERA	PERIOD		EPOCH	AGE ESTIMATES OF BOUNDARIES (in Ma)
Phanerozoic	Cenozoic	Quaternary		Holocene	0.010
				Pleistocene	1.7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late	96
				Early	138
		Jurassic		Late Middle Early	205
		Triassic		Late Middle Early	~240
	Paleozoic	Permian		Late Early	290
		Carboniferous Periods	Pennsylvanian	Late Middle Early	~330
			Mississippian	Late Early	360
		Devonian		Late Middle Early	410
		Silurian		Late Middle Early	435
		Ordovician		Late Middle Early	500
		Cambrian		Late Middle Early	~570[1]
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.

GPO 585-045/78049

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