DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

MINERAL RESOURCES OF THE FISH CREEK RIM WILDERNESS STUDY AREA, LAKE COUNTY, OREGON

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U.S. Geological Survey
Open-File Report 88-442

Prepared by the U.S. Geological Survey and the U.S. Bureau of Mines

for the U.S. Bureau of Land Management

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey

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1988

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 part of the Fish Creek Rim Wilderness Study Area (OR-001-117), Lake County, Oregon.

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SUMMARY

Abstract

At the request of the U.S. Bureau of Land Management, approximately 11,920 acres of the Fish Creek Rim Wilderness Study Area (OR-001-117) were evaluated for mineral resources (known) and mineral resource potential (undiscovered). In this report, the area studied is referred to as the "wilderness study area" or simply "the study area;" any reference to the Fish Creek Rim Wilderness Study Area refers only to that part of the wilderness study area for which a mineral survey was requested by the U.S. Bureau of Land Management. The study area is located in south-central Oregon, less than 1 mi northwest of Adel, Oregon and about 30 mi east of Lakeview, Oregon. No mineral resources were identified in the study area. There is low potential for oil and gas resources in the entire study area, and low potential for geothermal resources in the eastern part of the study area.

Character and Setting

The study area lies along the west side of Warner Valley less than 1 mi northwest of Adel, Oreg. (fig. 1). Elevations range from about 4,500 ft in Warner Valley to 6,932 ft at the top of Lynchs Rim. Topography is steep along the eastern and southern edges of the study area, whereas the western part of the study area is a flat tableland sloping gently to the west. The climate is semiarid and vegetation consists of sagebrush, desert bunchgrass, and many varieties of wildflowers. Scattered stands of juniper, aspen, white fir, and mountain mahogany are present along the higher parts of Lynchs Rim.

The study area is underlain by a sequence of Miocene (see appendixes for geologic time chart) basaltic to andesitic lava flows and interbedded tuffaceous sedimentary rocks. Younger faults related to regional basin and range extension have cut these rocks, the largest of which produced the uplift along Lynchs Rim. Other minor faults in the study area have displacements of less than 50 ft.

Identified Resources

There are no identified mineral resources in the study area. Investigation of localities favorable for resources of diatomite, zeolite, gold, silver, and mercury, as postulated in a 1985 U.S. Bureau of Land Management study, only indicated the presence of minor zeolite. Zeolite is used primarily for filtering liquids and as filler in such products as paper and paint.

Oil and gas lease applications were filed for most of the area, but these have expired. The eastern edge of the study area is in the Crump Geyser Known Geothermal Resource Area (KGRA). Energy resources have not been identified in the study area.

Mineral Resource Potential

Geologic, geochemical, and geophysical studies give no indications of significant mineralization in the study area. The eastern part of the study area lies in the Crump Geyser KGRA (fig. 2). The range-front fault, which

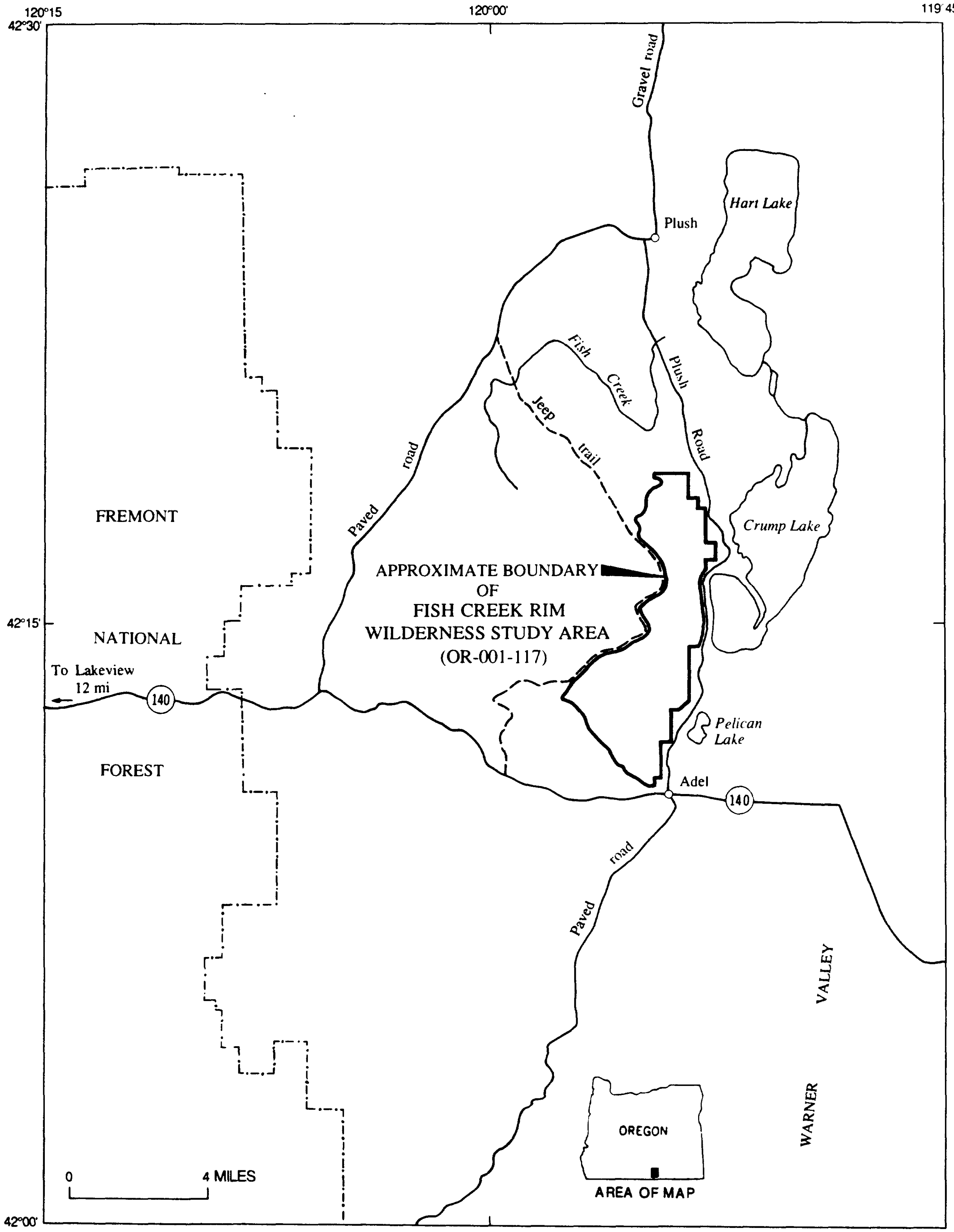

Figure 1. Index map showing location of the Fish Creek Rim Wilderness Study Area, Lake County, Oregon

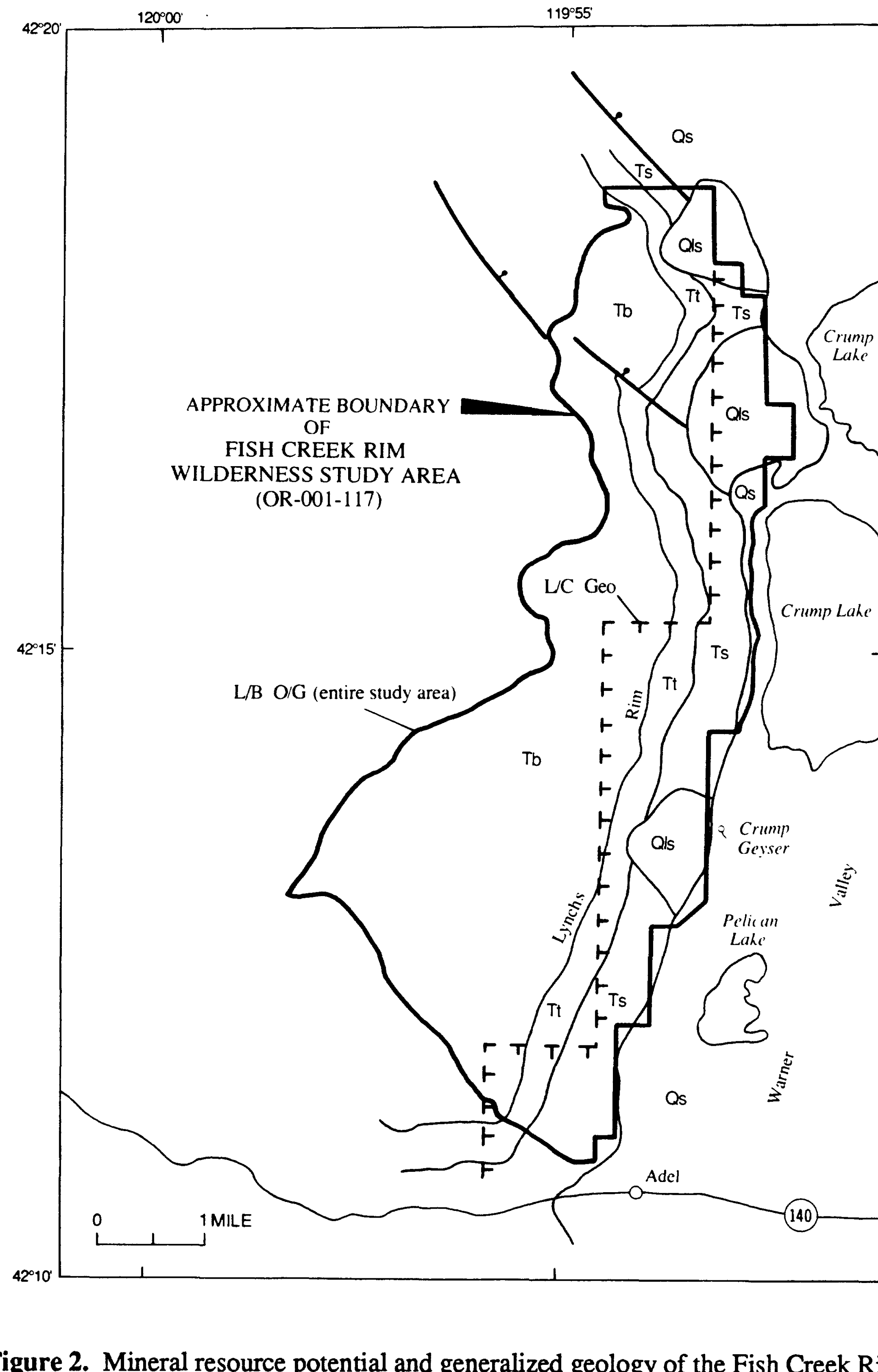

Figure 2. Mineral resource potential and generalized geology of the Fish Creek Rim Wilderness Study Area, Lake County, Oregon

EXPLANATION

L Area having low resource potential for specified commodity

Levels of certainty of assessment

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

Commodities

Geo Geothermal
O/G Oil and Gas

Correlation of map units

Qs	Quaternary	CENOZOIC
Qls	Quaternary	CENOZOIC
Tb	Tertiary	CENOZOIC
Tt	Tertiary	CENOZOIC
Ts	Tertiary	CENOZOIC

Description of map units

Qs Surficial deposits (Holocene or Pleistocene)--Mostly stream sand and gravel, fanglomerate, and eolian and lacustrine sediments
Qls Landslides (Holocene or Pleistocene)
Tb Basalt (Miocene)--Black to brown, commonly aphyric, vesicular basalt flows
Tt Tuffaceous sedimentary rocks (Miocene)--Includes air fall tuff and associated sedimentary rocks
Ts Steens Basalt (Miocene)--Black to dark-brown, vesicular to nonvesicular flows containing phenocrysts of plagioclase--Includes about 150 ft of older andesite

Contact
Normal fault--Bar and ball on downthrown side; dashed where approximately located
T T T Boundary of Crump Geyser Known Geothermal Resource Area; potential lies east of the boundary

Figure 2. Continued

has a displacement of at least 2,000 ft, runs along the entire east side of the study area, and may serve as a pathway for geothermal fluids. This part of the study area has low potential for geothermal resources (fig. 2).

The dominantly volcanic rocks exposed in the study area are unlikely to have significant hydrocarbon source beds, but carbonaceous source beds may underlie the study area at depth. The study area has low potential for oil and gas resources (Fouch, 1983).

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management and is the result of a cooperative effort by the U.S. Geological Survey and the U.S. Bureau of Mines. An introduction to the wilderness review process, mineral survey methods, and agency responsibilities was provided by Beikman and others (1983). The U.S. Bureau of Mines evaluates identified resources at individual mines and known mineralized areas by collecting data on current and past mining activities and through field examination of mines, prospects, claims, and mineralized areas. Identified resources are classified according to a system that is a modification of that described by McKelvey (1972) and U.S. Bureau of Mines and U.S. Geological Survey (1980). U.S. Geological Survey studies are designed to provide a 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. 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 Fish Creek Rim Wilderness Study Area is located in south-central Oregon along the west side of Warner Valley (fig. 1). Mineral surveys were requested for 11,920 acres of this area by the U.S. Bureau of Land Management. This region is typified by extensive lava flows of Miocene age and interbedded sedimentary rocks that have been cut by numerous faults into a series of broken, flat-topped, mountain blocks and intervening alluvial valleys. The northwestern part of the study area is situated on a plateau at an elevation of about 6,900 ft, with gentle topography of low, rolling hills and isolated ridges uplifted along minor faults. Along the east side of the study area, however, Lynchs Rim forms a steep escarpment that rises about 2,000 ft above Warner Valley. The climate is semiarid and vegetation consists of sagebrush, desert bunchgrass, and many varieties of wildflowers. Higher elevations in the study area support stands of juniper, aspen, white fir, and mountain mahogany.

The study area is located about 30 mi east of the town of Lakeview, Oreg. and less than 1 mi northwest of Adel, Oreg. (fig. 1). Access to the southern and western parts of the study area is by dirt roads leading from Oregon State Highway 140. Plush Road, leading north from the town of Adel, provides access to the eastern part of the study area.

Previous and Present Investigations

The stratigraphy and structure of the study area were described by Larson (1965) as part of a Ph.D. dissertation. The study area is included in reconnaissance geologic maps at a scale of 1:250,000 (Walker and Repenning, 1965) and 1:500,000 (Walker, 1977). Other regional geologic studies in southeastern Oregon that include the study area include those by Lawrence (1976), McKee and others (1983), Mankinen and others (1985, 1987), and Carlson and Hart (1987). Mathews and others (1983) described the geology, energy, and mineral resources of the study area. A regional aeromagnetic survey conducted by the U.S. Geological Survey (1972) includes the study area.

The U.S. Geological Survey conducted field investigations in the study area in the summer of 1986. The work included geologic mapping, geochemical sampling, and geophysical studies. Geochemical samples were collected from most stream drainages to obtain information about mineral suites and trace-element signatures associated with mineralizing systems.

The U.S. Bureau of Mines investigation was conducted by personnel from the Western Field Operations Center, Spokane, Wash., and consisted of prefield research, fieldwork, and report preparation phases between 1985 and 1987. Prefield studies included a literature search and an examination of Lake County, Oreg., and U.S. Bureau of Land Management mining claim and mineral lease records. U.S. Bureau of Mines, State of Oregon, and U.S. Bureau of Land Management mineral property files also were examined and pertinent data compiled. Fieldwork included a search for evidence of mining activity and mineralized sites in and near the study area.

Most fieldwork consisted of examination of tuff beds and basalt flows for diatomite, zeolite, gold, silver, and mercury postulated in a 1985 U.S. Bureau of Land Management report. Sixteen rock samples were collected during field investigations; 13 from tuffaceous beds and 3 from basalt flows. All samples were checked for radioactivity and fluorescence, and they were analyzed for antimony, arsenic, bismuth, cadmium, copper, gallium, gold, lead, molybdenum, silver, thallium, and zinc. Gold content was determined by fire assay-atomic absorption methods; other elements were analyzed by organic extraction methods. Samples of tuffaceous material were examined for diatomite by petrographic microscope and were tested for zeolite content by an ion-exchange-capacity method developed by Helfferich (1964). Nine samples testing positive for zeolite were further tested by X-ray diffraction.

Additional information concerning analytical and other testing methodologies, detection limits, and results are available in Benjamin (1987), and at the U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Ave., Spokane, WA., 99202.

Acknowledgments

U.S. Geological Survey authors were assisted in the field by U.S. Geological Survey geologists Gerilyn Andrews, D.R. Kietzman, and Cliff Taylor. Terry Neumann and Spencee Willett, U.S. Bureau of Mines geologists, assisted the U.S. Bureau of Mines author in the fieldwork. Appreciation is also extended to Douglas Troutman (U.S. Bureau of Land Management, Lakeview, Oreg.) for supplying information about road conditions and mining-related activity in and around the study area.

APPRAISAL OF IDENTIFIED RESOURCES

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There are no identified mineral resources and no mining claims in or within 1 mi of the study area. U.S. Bureau of Mines Mineral Industry Location System data show a mercury deposit near Adel; however, the deposit was not found. Several small gravel pits east of the study area have supplied minor amounts of construction material for local use.

According to the U.S. Bureau of Land Management (1985), the study area has a moderate favorability for gold, silver, and mercury resources in geothermally active areas, and moderate and low favorabilities for diatomite and zeolite, respectively, in tuffaceous interbeds. Sixteen rock samples collected by the U.S. Bureau of Mines have background or lower amounts of gold, silver, mercury, and nine other analyzed elements. Minor amounts of zeolite were detected in 9 of 13 tuffaceous samples. The zeolite, however, is not of sufficient quality and quantity to be of economic interest. Diatomite was not detected.

The eastern edge of the study area is within the boundary of the Crump Geyser Known Geothermal Resource Area (KGRA), and several geothermal test wells have been drilled on leases just east of the area. Most of the study area has been under lease application for oil and gas; however, all applications have recently expired. No energy resources have been identified in or near the study area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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Geology

The study area is in a region transitional between the Basin and Range and Columbia Plateau provinces. Extensive flood basalts and associated air-fall tuffs and sedimentary rocks of Miocene age underlie most of the region. Younger Basin and Range faulting has cut these rocks along northerly trends producing the subparallel north-trending mountain blocks and intervening alluviated valleys. The study area is cut by the Eugene-Denio fault zone, which is interpreted as part of the boundary zone between extended terrane of the Basin and Range province to the south and unextended terrane of the Columbia plateau to the north (Lawrence, 1976).

Within the study area, at least three separate periods of volcanism are recorded. The oldest deposits consist of a sequence of nearly flat-lying andesite flows about 23 Ma in age. The base of this sequence is not exposed, but about 150 ft of the sequence is present in the study area. The flows are light gray, dominantly aphanitic, and nonvesicular. Individual flows range in thickness from about 6 to 30 ft.

An overlying sequence of basalt flows about 750 ft thick are correlated with the Steens Basalt (Mankinen and others, 1985, 1987). Flows range from about 3 to 50 ft in thickness and are dark gray to black. Flows in this overlying sequence lack the distinctive large labradorite phenocrysts found at the type locality (Fuller, 1931), although slightly porphyritic flows are found in the lower part of the sequence. The Steens Basalt is about 15 Ma in age (Baksi and others, 1967).

A period of decreased volcanic activity is reflected in a sequence of tuffaceous sedimentary rocks and air-fall tuff that overlies the Steens Basalt. This sequence ranges in thickness from about 600 ft in the northern part of the study area to about 900 ft in the southern part. These rocks are white to buff, and include sandstone, siltstone, and beds of lapilli tuff up to 50 ft thick.

The youngest volcanic rocks in the study area comprise a sequence of basalt flows and flow breccia about 100 ft thick that underlies the broad plateau at the top of Lynchs Rim. These flows are typically medium gray, fine grained, aphanitic, and commonly highly vesicular.

Geochemical Studies

The reconnaissance geochemical study of the Fish Creek Rim Wilderness Study Area included collection, analysis, and evaluation of minus-80-mesh stream-sediment samples from 17 sites and nonmagnetic heavy-mineral-concentrate samples derived from stream sediments collected at 15 of the sites. The stream-sediment samples and the stream sediments from which the concentrates were derived were taken from the active alluvium in the stream channel.

Stream sediments were selected as a sample medium because they represent a composite of the rock and soil exposed upstream from the sample site. Nonmagnetic heavy-mineral-concentrate samples provide information about the chemistry of a limited number of minerals in rock material eroded from the drainage basin upstream from each sample site. Many of the minerals found in the nonmagnetic fraction of heavy-mineral concentrates may be ore forming or ore related, provided mineralization has been active in the area. The selective concentration of minerals permits determination of some elements that are not easily detected in bulk stream-sediment samples. Stream-sediment samples were sieved using 80-mesh stainless-steel sieves and the minus-80-mesh fraction was used for analysis. The heavy-mineral concentrate was obtained by panning minus-10-mesh stream sediment to remove most of the quartz, feldspar, organic materials, and clay-sized material. Bromoform was then used to remove light mineral grains from the panned concentrate. The resultant heavy-mineral concentrate was separated by use of an electromagnetic separator into three fractions: a magnetic fraction, chiefly magnetite; an intermediately magnetic fraction consisting largely of mafic minerals; and a nonmagnetic fraction that is composed dominantly of light-colored accessory minerals and primary and secondary ore-forming and ore-related minerals. Using a microsplitter, the nonmagnetic fraction was split into two fractions. One of these splits was used for analysis and the other for visual examination with a binocular microscope. In some instances, sample volume was too small to provide a split for visual examination. These samples were examined visually prior to grinding for analysis; archived splits for these samples contain no material not ground to fine powder.

All samples were analyzed semiquantitatively for 31 elements using direct-current arc emission spectrography (Grimes and Marranzino, 1968). Stream-sediment samples were also analyzed by inductively coupled argon plasma-atomic emission spectroscopy for antimony, arsenic, bismuth, cadmium, and zinc (Crock and others, 1987), and by atomic absorption for gold (O'Leary and Meier, 1986) and mercury (Crock and others, 1987). Analytical data were compiled for this report by M.S. Erickson (written commun., 1988).

Two slightly anomalous values of lead were found in nonmagnetic heavy-mineral-concentrate samples. The values, 300 and 200 parts per million (ppm), were found in concentrates from a site about 1.5 mi north of Crump Lake on the northeast side of the study area and from a site on the east side of the study area about 3 mi northwest of Crump Geyser, respectively. The sites are about 5 mi apart. No lead-bearing ore minerals were identified in the concentrates during microscopic examination. The anomalous values could be due to the presence of a lead artifact, such as a bullet fragment, or to lead oxide from a lead artifact in the samples; however, no artifacts were observed. The low lead values, the absence of a lead ore mineral in the samples, and the absence of elements normally associated with lead deposits in the anomalous concentrates strongly suggests that the lead values do not reflect significant concentrations of mineralized rock.

No other anomalous values for elements were found in these or other concentrate samples. No anomalous values were found for elements in stream-sediment samples.

Geophysical Studies

Geophysical evaluation of the mineral resources of the study area was based on interpretations of four kinds of geophysical surveys. These were aerial gamma-ray, aeromagnetic, gravity, and remote-sensing surveys.

Radiometric data were compiled by Geodata International, Inc. (1980) for the National Uranium Resource Evaluation program of the Department of Energy. The coverage consists of three east-west flightlines spaced at intervals of 3 mi and totaling 7 mi in length and a 3-mi segment of a north-south flightline. Flight altitudes ranged from 100 to 700 ft above the ground. Recordings were made of gamma-ray flux from radioactive isotopes of uranium, thorium, and potassium. Count rates were low over basalt flows. There was no indication of the presence of anomalous amounts of radioactive elements in the study area.

An aeromagnetic survey was flown over the study area at a constant barometric elevation of 7,000 ft above sea level (Plouff and Conradi, 1975). East-west flightlines were spaced at intervals of 1 mi. The aeromagnetic map shows a complex set of anomalies that reflect large variations of rock magnetization of the Tertiary volcanic rocks in the study area. Elongated magnetic highs generally overlie the older volcanic rocks along the base of Lynchs Rim and extend northwestward to follow that outcrop through the northern part of the study area. A 1- by 2-mi magnetic high overlies the youngest basalt flows in the southern part of the study area and a 1- by 4-mi magnetic low overlies the youngest basalt flows in the central part of the study area. The magnetic low may reflect reversely magnetized flow rocks (Mankinen and others, 1985) of the Steens Basalt beneath a thin caprock of younger basalt flows. An aeromagnetic map of the region with flightlines spaced at intervals of 2 mi and a flight elevation of 9,000 ft above sea level clarifies some of the regional-scale anomalies and also delineates a 5-mi-diameter magnetic low centered 1 mi southwest of the study area (U.S. Geological Survey, 1972).

The U.S. Geological Survey established 7 gravity stations along the edge of and within 3 mi outside the study area in 1986 (Plouff, 1987). These data supplemented an extensive set of data previously established outside the study area (Plouff, 1977). A gravity map prepared from these data shows a narrow, north-trending gravity high that extends through the study area (Donald Plouff, unpub. data, 1987). The high is bordered near the southern corner of the study area by a steep gradient along the west and northwest edges of a gravity low centered 3 mi to the south in Warner Valley. As indicated by the amount of closure around the gravity low in Warner Valley, about half of the gravity gradient reflects the contrast in density between tuffaceous sediments in Warner Valley and the surrounding volcanic rocks. The remaining half is attributed to the contrast in density between rocks beneath the sediments in Warner Valley and denser basement rocks to the west. The gravity gradient probably reflects the location of a zone of normal faulting that accompanied subsidence of a 5- by 8-mi basin in Warner Valley. The faulting, as depicted by the location of the steepest gravity gradients, hinges out just northeast of the southeast corner of the study area and 6 mi to the south. The central gravity high is bordered on the west by gradients along the east edge of a 6- by 8-mi gravity low. It is unknown if the gravity low reflects a small collapsed area beneath the basalt cap or an accumulation of low-density volcanic rocks. The gravity data coverage is too sparse to determine if this low is part of a larger low that may extend 10 mi farther to the south.

Linear features in LANDSAT multispectral scanner 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. 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 could reveal relations such as fracture control of mineralization.

Linear features of many orientations are well expressed on the surface in southeastern Oregon, except in areas underlain by volcanic rocks and alluvium. Locally, areas have preferred trends related to faults, if locally important, or to rock joint systems.

Trend concentration maps were made at 20-degree intervals of azimuth covering a range of 30 degrees. In the area east of longitude 120° W. and north of latitude 42° N., linear features are not well expressed owing to the nature of the surface cover.

Mineral and Energy Resource Potential

Geologic, geochemical, and geophysical studies give no indication of significant mineralization in the study area. Field examination of outcrops did not show evidence of any extensive or pervasive alteration associated with mineralization. Although hot-spring activity on the east side of the study area could be a source of mineralizing fluids, no geochemical anomalies associated with mineralization were found in that area or elsewhere in the study area. Therefore, there is no evidence of potential for metallic resources.

The eastern part of the study area lies within the Crump Geyser KGRA. The range-front fault, which has a displacement of at least 2,000 ft, runs along the entire east side of the study area and may serve as a pathway for geothermal fluids. This part of the study area has low potential, certainty level C, for geothermal resources (fig. 2).

The dominantly volcanic rocks exposed in the study area are unlikely to have significant hydrocarbon content, but older Tertiary sedimentary rocks containing carbonaceous source beds may underlie the study area at depth. High heat flow associated with volcanism and nearby hot-spring activity, however, would most likely have driven off any preexisting hydrocarbons. Fouch (1983) determined that the study area has a low to medium potential for petroleum resources. In this study, the entire study area is considered to have low potential, certainty level B, for oil and gas resources (fig. 2).

REFERENCES CITED

Baksi, A.K., York, Derek, and Watkins, N.D., 1967, Age of the Steens Mountain geomagnetic polarity transition: Journal of Geophysical Research, v. 72, no. 24, p. 6299-6308.

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.

Benjamin, D.A., 1987, Mineral resources of the Fish Creek Rim study area, Lake County, Oregon: U.S. Bureau of Mines Open-File Report MLA 60-87, 11 p.

Carlson, R.W., and Hart, W.K., 1987, Crustal genesis on the Oregon plateau: Journal of Geophysical Research, v. 92, no. B7, p. 6191-6206.

Crock, J.G., Briggs, P.H., Jackson, L.L., and Lighte, 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.

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

Fuller, R.E., 1931, The geomorphology and volcanic sequence of Steens Mountain in southeastern Oregon: University of Washington Press, Seattle, Wash., University of Washington Publications in Geology, v.3, no. 1, 130 p.

Geodata International, Inc., 1980, Aerial radiometric and magnetic survey, National Topographic Map, Adel, Oregon: U.S. Department of Energy Open-File Report GJBX-104 (80), v. 2, 145 p.

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.

Helfferich, Friedrich, 1964, A simple identification reaction for zeolites (molecular sieves): The American Mineralogist, v. 49, nos. 11 and 12, p. 1752-1754.

Larson, E.E., 1965, The structure, stratigraphy, and paleomagnetics of the Plush area, southeastern Lake County, Oregon: Ph.D. dissertation, University of Colorado, 166 p.

Lawrence, R.D., 1976, Strike-slip faulting terminates the Basin and Range Province in Oregon: Geological Society of America Bulletin, v. 87, p. 846-850.

Mankinen, E.A., Prévot, Michel, and Grommé, C.S., 1985, The Steens Mountain (Oregon) geomagnetic polarity transition; I, directional history, duration of episodes, and rock magnetism: Journal of Geophysical Research, v. 90, no. B12, p. 10,393-10,416.

Mankinen, E.A., Larson, E.E., Grommé, C.S., Prévot, Michel, and Coe, R.S., 1987, The Steens Mountain (Oregon) geomagnetic polarity transition; 3, its regional significance: Journal of Geophysical Research, v. 92, no. B8, p. 8057-8076.

Mathews, G.W., Blackburn, W.H., and Chapell, D.L., 1983, Assessment of geology, energy, and mineral (GEM) resources, Crump Lake GRA (OR-010-25), Lake County, Oregon: prepared by TERRADATA, Lakewood, Colo., BLM contract YA-553-CT2-1042.

McKee, E.H., Duffield, W.A., and Stern, R.J., 1983, Late Miocene and early Pliocene basaltic rocks and their implications for crustal structure, northeastern California and south-central Oregon: Geological Society of America Bulletin, v. 94, p. 292-304.

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

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

Plouff, Donald, 1977, List of principal facts and gravity anomalies for an area between Orovada, Nevada and Adel, Oregon: U.S. Geological Survey Open-File Report 77-683, 40 p.

_____1987, Gravity observations by the U.S. Geological Survey in northwest Nevada, southeast Oregon, and northeast California, 1984-1986: U.S. Geological Survey Open-File Report 87-639, 33 p.

Plouff, Donald, and Conradi, Arthur, Jr., 1975, Gravity and magnetic profiles and maps, Crump Geyser area, Oregon: U.S. Geological Survey Open-File Report 75-346, 2 p., 12 pls.

U.S. Bureau of Land Management, 1985, Oregon Wilderness Environmental Impact Statement, v. 2, p. 81-93.

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 Adel and parts of the Burns, Boise, and Jordan Valley 1 x 2° quadrangles, Oregon: U.S. Geological Survey Open-File Report 72-390, scale 1:250,000.

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

Walker, G.W., and Repenning, C.A., 1965, Reconnaissance geological map of the Adel Quadrangle, Lake, Harney, and Malheur Counties, Oregon: U.S. Geological Survey Miscellaneous Geological Investigations Map I-446, scale 1:250,000.

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 →

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

LEVEL OF CERTAINTY →

Abstracted with minor modifications from:

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

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.