Mineral Resources of the Sheepshead Mountains, Wildcat Canyon, and Table Mountain Wilderness Study Areas, Malheur and Harney Counties, Oregon

U.S. GEOLOGICAL SURVEY BULLETIN 1739-A

Chapter A

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U.S. GEOLOGICAL SURVEY BULLETIN 1739

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
ALVORD DESERT REGION, OREGON

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys 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 Sheepshead Mountains (OR–002–072C), Wildcat Canyon (OR–002–072D), and Table Mountain (OR–002–072I) Wilderness Study Areas, Malheur and Harney Counties, Oregon.

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Mineral Resources of the Sheepshead Mountains, Wildcat Canyon, and Table Mountain Wilderness Study Areas, Malheur and Harney Counties, Oregon

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SUMMARY

Abstract

The contiguous Sheepshead Mountains, Table Mountain, and Wildcat Canyon Wilderness Study Areas are located in the Sheepshead Mountains of Malheur and Harney Counties, southeastern Oregon. At the request of the U.S. Bureau of Land Management, a total of 45,705 acres of the Sheepshead Mountains, 34,830 acres of the Wildcat Canyon, and 25,185 acres of the Table Mountain Wilderness Study Areas were studied. In this report, the area studied is referred to as "the wilderness study area," or simply "the study area". Geological, geochemical, geophysical, and mineral surveys were conducted by the U.S. Geological Survey and the U.S. Bureau of Mines in 1986 to assess the mineral resources (known) and mineral resource potential (undiscovered) of the study area. No mining claims have been recorded or prospects found in any of the three study areas. An occurrence of impure diatomite totaling about 440,000 tons is present in the Wildcat Canyon Wilderness Study Area. No resources were identified in the Sheepshead Mountains, Wildcat Canyon, and Table Mountain Wilderness Study Areas.

Parts of the Sheepshead Mountains, Wildcat Canyon, and Table Mountain Wilderness Study Areas have low resource potential for gold and silver. A high resource potential exists for diatomite in the Wildcat Canyon Wilderness Study Area, and a low resource potential exists for diatomite in the Table Mountain Wilderness Study Area. The geothermal energy resource potential for direct heat utilization is moderate along major range-bounding faults in all three wilderness study areas. All three study areas have low potential for oil and gas.

Manuscript approved for publication, April 26, 1988.

Character and Setting

The Sheepshead Mountains, Wildcat Canyon, and Table Mountain Wilderness Study Areas (fig. 1) are located in the Sheepshead Mountains of Malheur and Harney Counties, Oregon, about 65 mi southeast of Burns, Oregon. The area is in the Basin and Range physiographic province, which is characterized by horst-and-graben structure that results in fault-block mountain ranges and intervening basins. The Sheepshead Mountains are mainly an upland of gentle relief, but steep escarpments as much as 1,000 ft high have formed along major faults in the area. The Sheepshead Mountains area is underlain by gently east- and southeast-dipping Miocene lava flows (see appendixes for geologic time chart) that range in composition from basalt to andesite. A few thin ash-flow tuffs and tuffaceous sedimentary rocks are locally interbedded with and overlie the lava flows. Quaternary basalt covers the northeast edge of the Sheepshead Mountains. Numerous normal faults cut the Miocene strata.

There are no claims, prospects, or workings in the Sheepshead Mountains, Wildcat Canyon, or Table Mountain Wilderness Study Areas. In the past, geothermal and oil and gas leases have covered parts of the Sheepshead Mountains and Table Mountain Wilderness Study Areas, but no leases are active. No geothermal or oil and gas exploration has been recorded.

Identified Resources

An occurrence of impure diatomite totaling about 440,000 tons is located in the Wildcat Canyon Wilderness Study Area. The impurity of the diatomite and the distance from markets make the occurrence uneconomic. The Sheepshead Mountains, Wildcat Canyon, and Table Mountain Wilderness Study Areas have no identified resources.

Mineral and Energy Resource Potential of the Sheepshead Mountains Wilderness Study Area

The Sheepshead Mountains Wilderness Study Area, which is underlain by several thousand feet of basalt, has low resource potential for gold and silver near some fault zones in the east-central part of the study area. The region is characterized by high heat flow, and hot springs are

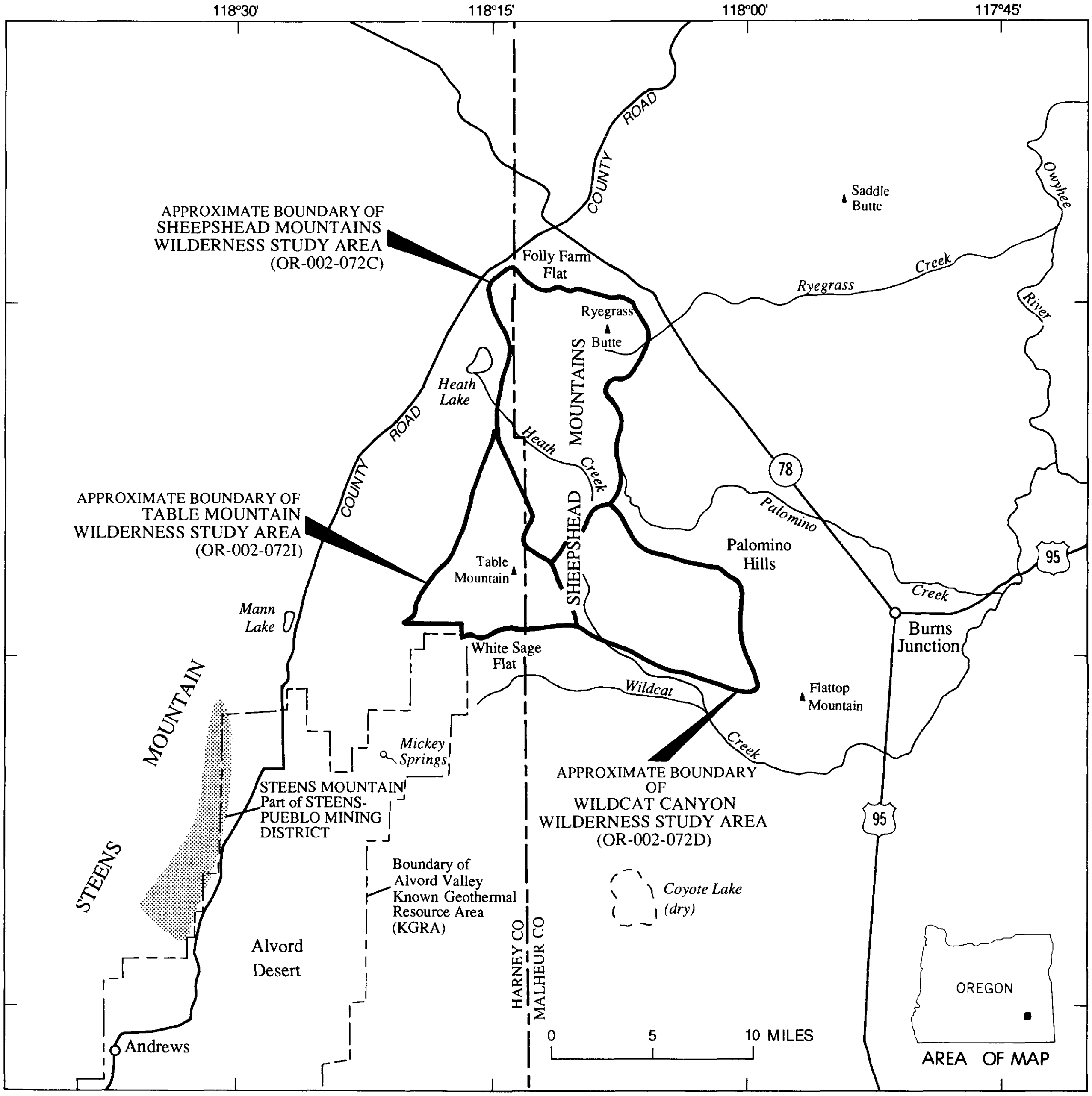

Figure 1. Index map showing location of Sheepshead Mountains, Wildcat Canyon, and Table Mountain Wilderness Study Areas, Malheur and Harney Counties, Oregon.

present as close as 12 mi to the study area. A moderate potential for geothermal energy resources appropriate for direct heat utilization is assigned to the western part of the study area adjacent to major range-bounding faults. The resource potential for oil and gas is low throughout the study area.

Mineral and Energy Resource Potential of the Wildcat Canyon Wilderness Study Area

The Wildcat Canyon Wilderness Study Area has low resource potential for gold and silver near some fault zones in the northern and western parts of the study area. The area has high potential for small, impure diatomite resources associated with a diatomite occurrence at the east side of the study area. The southern part of the study area has moderate resource potential for geothermal energy near range-bounding faults. The resource potential for oil and gas is low throughout the Wildcat Canyon Wilderness Study Area.

Mineral and Energy Resource Potential of the Table Mountain Wilderness Study Area

The Table Mountain Wilderness Study Area has a low resource potential for gold and silver near a fault zone in the southern part of the area. A Pleistocene lake basin on the south side of the study area has low potential for diatomite resources. The study area lies adjacent to the Alvord Valley Known Geothermal Resource Area (KGRA). The geothermal energy resource potential is moderate along range-bounding faults near the west and south edges of the study area. The resource potential for oil and gas is low throughout the Table Mountain Wilderness Study Area.

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 a system that is a modification of that described by McKelvey (1972) and U.S. Bureau of Mines and U.S. Geological Survey (1980). Studies by the 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 methods and terminology as they apply to these surveys were discussed by Goudarzi (1984). See the appendixes for the definition of levels of mineral resource potential, certainty of assessment, and classification of identified resources.

Location and Physiography

The Sheepshead Mountains (OR–002–072C), Wildcat Canyon (OR–002–072D), and Table Mountain (OR–002–072I) Wilderness Study Areas are located in the Sheepshead Mountains of Malheur and Harney Counties, Oregon, about 65 mi southeast of Burns, Oregon (fig. 1). The U.S. Bureau of Land Management requested that 45,705 acres of the Sheepshead Mountains Wilderness Study Area, 34,830 acres of the Wildcat Canyon Wilderness Study Area, and 25,185 acres of the Table Mountain Wilderness Study Area be evaluated for mineral resources and mineral resource potential. The three wilderness study areas are contiguous and are referred to either individually or as "the study area" throughout this report. Also, as used herein, "Sheepshead Mountains" refers to the mountain range containing the Sheepshead Mountains, Wildcat Canyon, and Table Mountain Wilderness Study Areas; whereas "Sheepshead Mountains Wilderness Study Area" refers to a designated area within the Sheepshead Mountains (fig. 1).

The Sheepshead Mountains are near the northwest edge of the Basin and Range physiographic province and adjacent to the Owyhee Uplands and High Lava Plains provinces (Dicken, 1965). The climate is semi-arid, characteristic of southeast Oregon. The sparsely vegetated mountains are mainly an upland of low relief with steep escarpments as much as 1,000 ft high along major faults in the area. Oregon Highway 78 provides access on the northeast side of the study area; unimproved dirt roads bound the individual wilderness study areas.

Previous and Present Studies

Few geologic studies have been conducted in the Sheepshead Mountains. Reconnaissance maps by Walker and Repenning (1965) and Greene and others (1972) show the basic geologic setting of the area. Other workers have collected a few rock samples for regional geochemical and geochronologic studies (Hart and Mertzman, 1982; Hart and Carlson, 1985). Mathews and others (1983) assessed the energy and mineral resources of the area in a report prepared for the U.S. Bureau of Land Management. Previous geophysical surveys include aerial radiometric and

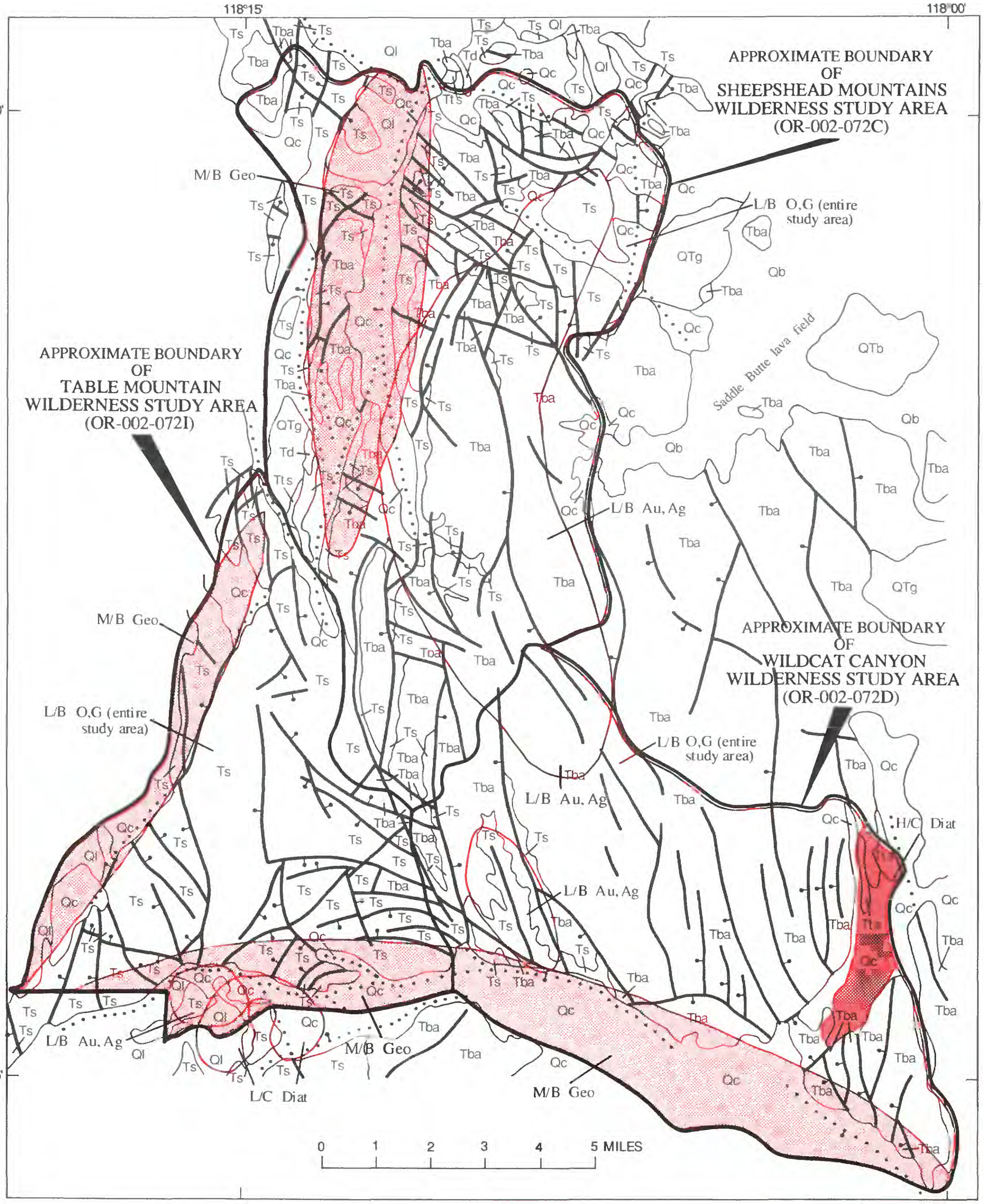

Figure 2. Map showing mineral resource potential and geology of the Sheepshead Mountains, Wildcat Canyon, and Table Mountain Wilderness Study Areas, Malheur and Harney Counties, Oregon. Geology mapped by Craig Harwood, Jenda Johnson, Scott Minor, John Muntean, Dave Sherrod, Dean Vander Meulen, and Tom Vercoutere during May and June 1986.

magnetic profiles (Geodata International, Inc., 1980; High Life Helicopters, Inc., and QEB, Inc., 1981) for the U.S. Department of Energy and an aeromagnetic map (U.S. Geological Survey, 1972).

Field studies by the U.S. Geological Survey were conducted in 1986 and include geologic mapping, geochemical studies, and a gravity survey. Rock and stream-sediment samples were collected to supply background geochemical information and to identify areas containing anomalous concentrations of economic or indicator elements.

The U.S. Bureau of Mines conducted a survey of the study area in 1986, which included an investigation of U.S. Bureau of Land Management mining claim and mineral lease records. U.S. Bureau of Mines field studies were directed chiefly towards locating mineral deposits and mineralized areas in order to determine if any mining activity remained unreported. Eleven samples were analyzed for zeolites and ten samples were analyzed for diatomite. Fifteen reconnaissance pan samples of alluvium were collected in the study area and one pan sample was taken from an inactive claim north of the Sheepshead Mountains Wilderness Study Area. Details of the U.S. Bureau of Mines sampling procedures and results for all three wilderness study areas are reported by Graham and Buehler (1987). Analytical data are available at U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Ave., Spokane, WA 99202.

Acknowledgments

Roger Brittain of the U.S. Bureau of Land Management, Burns, Oregon, assisted the U.S. Bureau of Mines personnel during their examination of the study area. The Davis family at the Alvord Ranch generously provided room and board for U.S. Geological Survey personnel.

EXPLANATION

Area with high mineral resource potential (H)

Area with moderate mineral resource potential (M)

Area with low mineral resource potential (L)

Levels of certainty of assessment

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

Commodities

Au	Gold
Ag	Silver
Diat	Diatomite
Geo	Geothermal
O, G	Oil, Gas

Geologic map units

Ql	Lacustrine and playa deposits (Quaternary)
Qc	Colluvium (Quaternary)
Qb	Younger basalt (Quaternary)
QTb	Older basalt (Quaternary or Tertiary)
QTg	Gravel and conglomerate (Quaternary and Tertiary)
Tts	Tuff and tuffaceous sedimentary rocks (Tertiary)
Tdc	Devine Canyon Ash-flow Tuff (Tertiary)
Tba	Basalt, basaltic andesite, andesite, and dacite (Tertiary)
Ts	Steens Basalt (Tertiary)
	Contact—Approximately located
	Fault—Dotted where concealed. Ball and bar on downthrown side

Figure 2. Continued.

APPRAISAL OF IDENTIFIED RESOURCES

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U.S. Bureau of Mines

Mining and Exploration History

No mining claims or prospects have been located within the Sheepshead Mountains, Wildcat Canyon, or Table Mountain Wilderness Study Areas. The nearest mining district is the Steens-Pueblo district, which lies about 18 mi southwest of the Table Mountain Wilderness Study Area (Bradley, 1982).

In 1984, two oil and gas leases covered 3,700 acres in the Sheepshead Mountains Wilderness Study Area and nine leases covered 18,000 acres in the Table Mountain Wilderness Study Area. As of March, 1987, the leases had expired and there were no leases in any of the wilderness study areas. No oil and gas exploration has been recorded within the study areas (King, 1985; Olmstead, 1986; Graham and Buehler, 1987).

The Table Mountain Wilderness Study Area is adjacent to the Alvord Valley Known Geothermal Resource Area. In 1984, six geothermal leases covered 7,376 acres in the Table Mountain Wilderness Study Area. As of March 1987, the leases had expired and there were no geothermal leases in any of the wilderness study areas.

Mineral Deposits

No mineral or energy resources were identified in the study area. The Geology, Energy, and Minerals (GEM) study suggested that areas favorable for diatomite occur within the study areas (Mathews and others, 1983). In the

Table Mountain Wilderness Study Area, a sequence of sedimentary rocks near White Sage Flat contains interbedded sandstone and diatomite. Microscopic analysis revealed that the diatomite contains too much carbonate, clay, and quartz impurities to be acceptable for industrial or commercial use. In the Wildcat Canyon Wilderness Study Area, an estimated 440,000 tons of diatomite is present as a mineral occurrence. Whole rock analyses indicate that this diatomite contains 7 to 14 percent aluminum oxide and 1 to 2 percent iron oxide, making the deposit unsuitable for most industrial uses.

Minor amounts of minute gold flakes were found in pan samples of alluvium in the Wildcat Canyon and Table Mountain Wilderness Study Areas. The gold is not present in sufficient quantities to be considered an identified resource.

There are no economic occurrences of zeolites in the study area. All materials tested for zeolites were found to contain significant quantities of clay (smectite) but little or no zeolites. The amount and quality of clay present did not warrant further evaluation as a resource.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By David R. Sherrod, Andrew Griscom, Robert L. Turner, *and* Scott A. Minor
U.S. Geological Survey

Geology

The Sheepshead Mountains are part of the Basin and Range province, which is characterized by horst-and-graben structure that results in fault-block mountain ranges and intervening basins. In Oregon, the basins are largely closed depressions that lack through-going drainage systems. Most of the major basins trend north to northeast, parallel to range-front fault escarpments.

The oldest unit exposed in the Sheepshead Mountains is the Steens Basalt, a series of alkali-olivine to tholeiitic flood basalt lava flows that was erupted about 15 to 16 million years ago (Ma) (for example, Mankinen and others, 1987). In the Sheepshead Mountains, the Steens Basalt is at least 1,200 ft thick; the base is not exposed (fig. 2 and pl. 1). The lava flows probably issued largely from north-northeast-trending dike swarms located about 20 mi to the southwest at Steens Mountain. No feeder dikes of Steens Basalt were found in the Sheepshead Mountains. The Steens Basalt is unaltered and unmineralized throughout the Sheepshead Mountains.

A unit of interfingering basalt, basaltic andesite, platy andesite, and dacite concordantly overlies the Steens Basalt. This younger sequence contains minor interbedded tuff and tuffaceous sedimentary rocks, types of rocks that are extremely rare in the Steens Basalt. The tuffaceous rocks are more easily eroded than the intervening lava flows. Consequently, the lava flows and softer tuffaceous beds erode into prominent ledges and low slopes, respectively. Though thin, the sedimentary interbeds probably indicate a lower eruption rate for the younger lava sequence relative to that of the Steens Basalt, and (or) perhaps slight subsidence to allow the accumulation of sediment. Potassium-argon whole-rock ages from lava flows near the top of the sequence are 11.71±0.65 Ma and 11.17±0.65 Ma (Hart and Mertzman, 1982).

The Devine Canyon Ash-flow Tuff was deposited locally in the northern and western parts of the Sheepshead Mountains about 9 Ma (Walker, 1979). This tuff is widespread west of the Sheepshead Mountains and was erupted from a source to the west, probably in the Harney Basin area 40 mi distant (Greene, 1973). Sandstone and conglomerate form a thin sequence of beds above the Devine Canyon Ash-flow Tuff in the Heath Lake area. In the southeast corner of the Sheepshead Mountains, the presence of diatomite with sandstone (in unit Tts, fig. 2 and pl. 1) indicates that some of the late Miocene and Pliocene basins contained lakes.

In latest Pliocene(?) and Quaternary time, lava flows of high-alumina basalt erupted from vents in the Saddle Butte lava field at the northeast edge of the Sheepshead Mountains. The vents are preserved as small low lava cones and the flows extend as far as 12 mi to the northeast (Walker, 1977). A potassium-argon whole rock age of 0.43±0.09 Ma was reported by Hart and Mertzman (1982) for one of the lava flows in the Saddle Butte lava field. Flow units of at least two ages can be distinguished by the degree of soil formation on flow surfaces.

Pleistocene and Holocene alluvium and colluvium has accumulated in the drainages and on the slopes of the Sheepshead Mountains and in the basins that surround the mountains. Several of the basins are closed depressions that contained large pluvial lakes during Pleistocene glacial epochs. As a result, the basins are ringed by shoreline deposits as much as 100 ft above the present valley floors. These deposits were created, in part, by wave action that reworked the surrounding talus and alluvium during high water levels.

Normal faulting formed the structural and topographic grain of the Sheepshead Mountains, and these faults can be grouped according to orientation. North-northwest- to north-northeast-striking faults have the greatest offset—as much as 1,000 ft. One of these major faults is expressed as the conspicuous escarpment that forms the west side of the Sheepshead Mountains.

Faults of a second group strike northwest to west-northwest and generally have offsets of less than 100 ft. They are on trend with and may be related to the Brothers fault zone, a northwest-trending zone of en echelon normal faults that extends across southeastern Oregon (Lawrence, 1976; Walker and Nolf, 1981).

A third group of faults are parallel to a broadly curving valley that bounds the Sheepshead Mountains on the south. This valley, which includes Mickey Basin, White Sage Flat, and Wildcat Creek, probably results from a system of arcuate, concave-to-the-south normal faults exposed there. These faults may be part of a partially buried, caldera-related(?) ring-fault system that may have formed in the early Miocene during eruption of welded tuff of the Pike Creek Formation (Hook, 1981). Part of the fault system remained active or was reactivated later, because Steens Basalt and overlying middle Miocene lava flows are cut by faults in the arcuate zone.

The ages of faulting in the study area are poorly known. Many faults are younger than 11–12 Ma, which is the age of the upper part of the lava flow sequence that concordantly overlies the Steens Basalt in much of the Sheepshead Mountains. In the southwestern part of the study area, however, where Steens Basalt is the only rock unit exposed, faults may be as old as 15 Ma. No faults cut the Quaternary basalt of the Saddle Butte lava field northeast of the Sheepshead Mountains, and Quaternary surficial deposits are undeformed throughout the Sheepshead Mountains. However, a fault near Mickey Basin southwest of the Sheepshead Mountains cuts alluvium and may be of Holocene age (Hook, 1981).

Between 9 and 11 Ma, major tilting and uplift occurred in the Sheepshead Mountains. An angular unconformity of as much as 18° separates the 9 Ma Devine Canyon Ash-flow Tuff from underlying middle Miocene basalt flows near Folly Farm Flat on the northwest side of the Sheepshead Mountains. The tuff, which is nearly flat-lying, is exposed only in topographically low areas near Folly Farm Flat and Heath Lake. Thus, after the eruption of the lava 11–12 Ma, and before the emplacement 9 Ma of the Devine Canyon Ash-flow Tuff, the volcanic and sedimentary rocks in the Sheepshead Mountains were tilted up to 18° or more, probably as a result of normal faulting. In addition to the tilting of strata, it is likely that some of the topographic relief between basins and mountains began to develop, as suggested by the limited distribution of the Devine Canyon Ash-flow Tuff.

Geochemical Studies

A reconnaissance geochemical survey was conducted in the Sheepshead Mountains, Wildcat Canyon, and Table Mountain Wilderness Study Areas. Minus-80-mesh stream sediments, heavy-mineral concentrates derived from stream sediments, and rocks were selected as the sample media in this study. Samples were collected from 116 sites for stream sediments and heavy-mineral concentrates, and from 34 outcrops for rocks. The heavy-mineral concentrates were passed through magnetic separators; material obtained after processing the heavy-mineral concentrates will be referred to as nonmagnetic concentrate in this report.

Bulk stream sediment represents a composite of the rock and soil exposed upstream from the sample site. The heavy-mineral concentrate represents the heavy-mineral components of rocks exposed in the drainage basin, and could include ore-forming and ore-related minerals if mineralization occurred in the drainage basin. The concentrating of samples permits detection of some elements that might remain undetected in bulk stream sediment.

Rock samples were taken from unmineralized outcrops, altered rocks in fault zones, and stream float. Samples that appeared fresh and unaltered were collected to provide information on geochemical background values. Altered samples were collected to determine the suite of elements associated with the observed alteration or mineralization. In this study, concentration levels are deemed anomalous when they exceed twice the concentration of the average rock composition (Parker, 1967).

All samples were analyzed semiquantitatively for 31 elements using direct-current arc emission spectrographic methods; rock and stream-sediment samples were analyzed by the method described by Crock and others (1987) and nonmagnetic heavy-mineral concentrates by the method described by Grimes and Marranzino (1968). Certain elements were also analyzed by other more precise methods: antimony, arsenic, bismuth, cadmium, and zinc were analyzed by inductively coupled argon plasma-atomic emission spectroscopy, and gold and mercury were analyzed by atomic absorption (methods described in Crock and others, 1987). A split of each of the heavy-mineral concentrate samples was examined with a binocular microscope for ore and ore-related minerals. The analytical data are by M.S. Erickson (written commun., 1986).

Stream-sediment and nonmagnetic heavy-mineral-concentrate samples from several parts of the study area have slightly anomalous concentrations of arsenic, mercury, gold, and silver. The largest anomalies are associated with samples collected near major north- or north-northwest-trending faults in the southern part of the Sheepshead Mountains Wilderness Study Area and the northwestern part of the Wildcat Canyon Wilderness Study Area. In these areas, stream-sediment samples contain slightly anomalous levels of arsenic (10–17 parts per million, ppm) and mercury (as much as 0.61 ppm), and the nonmagnetic concentrate samples are enriched in silver (1 to 10 ppm). The only gold (100 ppm) found by the geochemical survey occurred in one nonmagnetic concentrate sample from the Sheepshead Mountains Wilderness Study Area. Stream-sediment samples collected at a site in the southwestern part of the Table Mountain Wilderness Study Area yield anomalous values of arsenic (as much as 13 ppm). A rock sample from this site contains an anomalous concentration of arsenic (33 ppm).

Several rock samples collected in the Wildcat Canyon Wilderness Study Area have slightly anomalous concentrations of silver (3 to 5 ppm) and arsenic (generally 10 to 15 ppm, but as much as 70 ppm). These samples were collected from lava flows of Steens Basalt and from the overlying sequence of basalt, basaltic andesite, andesite, and dacite lava flows. The outcrops from which the anomalous rock samples were collected appear unaltered.

Anomalous amounts of arsenic and mercury are commonly associated with disseminated epithermal gold mineralization (Lewis, 1982), but there is no geologic evidence for epithermal mineralization in the study area. Most of the anomalous samples were collected along or near major faults, suggesting that the metals were deposited during epithermal mineralization in rocks older than and prior to the eruption of the Steens Basalt; metals were subsequently leached and remobilized by hydrothermal fluids moving up along some of the major normal faults in the area. The anomalies are very slight, which is consistent with the lack of visible silicification, sinter, pyrite, rock bleaching, or other signs of epithermal mineralization.

Geophysical Studies

An aeromagnetic survey of the Sheepshead Mountains, Wildcat Canyon, and Table Mountain Wilderness Study Areas was flown for the U.S. Geological Survey by a private company in 1972 (U.S. Geological Survey, 1972). The aeromagnetic data were collected at a constant flight elevation of 9,000 ft above sea level along parallel east-west flightlines spaced approximately 2.0 mi apart.

Additional aeromagnetic data are available in the atlases on the Adel and Burns quadrangles (scale 1:500,000) published for the Department of Energy (Geodata International, Inc., 1980; High Life Helicopters, Inc., and QEB, Inc., 1981). These data consist of aeromagnetic profiles flown east-west by helicopter at an average height of 400 ft above ground and a profile spacing of 3 mi. A total of 11 of these profiles cross the three wilderness study areas.

Variations in the Earth's magnetic field indicated on an aeromagnetic residual map are generally caused by variations in the amounts of magnetic minerals in different rock units, magnetite being the common magnetic mineral in the study area. In volcanic terrane, the polarity of the initial thermal remanent magnetization is also important. Magnetic minerals, where locally either concentrated or absent, may cause a high or low magnetic anomaly, respectively, 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 flank of the magnetic anomaly because at the magnetic latitude of the study area the inclination of the Earth's main magnetic field is relatively steep (68° below the horizontal).

The aeromagnetic patterns trend north or northeast to northwest, parallel to the main faults in the area. Sources of individual magnetic anomalies range from 1 to 3 mi wide and from 4 to 10 mi long. The anomalies are ordinary in amplitude and appearance and do not appear to indicate any resources of economic significance. Because of the preponderance of lava flows and other volcanic rocks in the area, the majority of the anomalies are probably caused by volcanic rocks. The survey was, in general, flown 3,000–4,500 ft above the surface of the ground, a distance sufficiently great to suppress most of the short wave-length anomalies generated by the smaller rock units at or near the surface.

A gravity survey of this region was conducted by the U.S. Geological Survey in 1986 to supplement data already available. Station spacing ranged from 2 to 10 mi, and about 20 stations were situated in the study area. The Bouguer gravity anomaly field is relatively featureless, sloping down to the northwest across the area with a relief of about 18 mGal along a distance of about 20 mi. The gravity data do not appear to define any features of possible economic interest.

Aerial gamma ray spectrometer measurements were made along 3-mi-spaced profiles by Geodata International, Inc. (1980), and High Life Helicopters, Inc., and QEB, Inc. (1981). The results show no statistically significant anomalies for uranium, potassium and thorium in the study area.

Mineral and Energy Resource Potential of the Sheepshead Mountains Wilderness Study Area

Gold and Silver

The closest known occurrences of gold are in the Steens-Pueblo mining district, about 18 mi to the southwest (fig. 1). This district contains early Miocene and older strata exposed beneath the Steens Basalt in the range-front escarpments of the Steens and Pueblo Mountains. The mineralization in the Steens-Pueblo mining district consists of silicified zones and fractures in the volcanic rocks (Williams and Compton, 1953; Brooks, 1963). Presumably, mineralization occurred prior to the eruption of the thick sequence of Steens Basalt.

Minor and others (1987) reasoned that undiscovered epithermal gold deposits may exist in the pre-Steens strata of the Steens-Pueblo mining district at Steens Mountain, on the basis of sporadic gold values, the presence of an anomalous suite of gold-indicator elements (arsenic, barium, mercury, and molybdenum), mercury deposits, and alteration types. Conceivably, similar deposits may lie buried beneath the lava flows in the Sheepshead Mountains Wilderness Study Area.

Within the Sheepshead Mountains Wilderness Study Area, stream sediment samples containing anomalous concentrations of arsenic, mercury, gold, and silver are associated with normal faults. These elements were probably remobilized by hydrothermal fluids moving up the faults. The gold and silver concentrations are too low to define the presence or extent of mineralization at depth. The broad area in the central and eastern part of the wilderness study area containing geochemical anomalies along faults has low resource potential, certainty level B, for gold and silver (fig. 2). Any possible mineralized zones are concealed beneath several thousand feet of Miocene basalt and andesite.

Geothermal Energy

The Sheepshead Mountains Wilderness Study Area is in the Basin and Range province, which is characterized by high heat flow values—84–104 milliwatts per square meter (mW/m2) (Lee and Uyeda, 1965). The study area lies north of the Alvord Valley KGRA. The Alvord Valley geothermal system is not magmatic in origin, but results from the deep circulation of meteoric waters along major faults (Cleary and others, 1981). Inasmuch as the wilderness study area lies at the north end of the valley-forming graben that contains the Alvord Valley geothermal system, it is possible that some heat from that system may be convected to or near the surface in the wilderness study area. However, there are no hot springs or other indications of recent or active geothermal systems in the study area. The western part of the wilderness study area that contains major range-bounding faults favorable for upwelling geothermal fluids has moderate resource potential, certainty level B, for geothermal energy.

Oil and Gas

The oil and gas resource potential of the entire Sheepshead Mountains Wilderness Study Area is low, certainty level B. The Cenozoic volcanic rocks exposed in the area are not source rocks, nor are the few interbedded sedimentary strata. There are no surficial tar or oil seeps or other evidence of hydrocarbon source beds or reservoirs.

There remains the possibility that source or reservoir rocks lie buried beneath the Neogene volcanic cover of the wilderness study area. This seems unlikely, however, for reasons summarized by Fouch (1983):

(1) Most pre-Tertiary rocks in the region have undergone incipient metamorphism, indicating a petroleum maturation level too high to preserve stable hydrocarbons;

(2) Eocene and Oligocene beds locally contain coal of a lignitic rank, and could only yield gas where buried much more deeply.

Gas shows have been detected in drill holes that penetrated upper Tertiary strata in local basins elsewhere in the region (Stewart and Newton, 1965; D.L. Olmstead, personal commun., 1988). Since carbonaceous beds may underlie or be interbedded with volcanic rocks at depth, there is a low resource potential for oil and gas in the study area (Fouch, 1983).

Mineral and Energy Resource Potential of the Wildcat Canyon Wilderness Study Area

Gold and Silver

The mineral resource potential is low, certainty level B, for gold and silver deposited along faults in the northern and western parts of the Wildcat Canyon Wilderness Study Area, on the basis of geochemical anomalies in stream-sediment and rock samples. Deposits similar to those found in the Steens-Pueblo mining district at Steens Mountain, 20 mi southwest, conceivably could underlie the wilderness study area (see discussion of gold for Sheepshead Mountains Wilderness Study Area).

Diatomite

In the eastern part of the Wildcat Canyon Wilderness Study Area, a mineral occurrence contains an estimated 440,000 tons of impure diatomite, with several percent of aluminum oxides and iron oxides. The diatomite is part of a sedimentary sequence of limited extent comprising sandstone, diatomite, and reworked volcanic ash. The mineral occurrence probably accounts for most of the diatomite present in the area because it is near the center of the basin that contains the sedimentary rocks; though poorly exposed, the relative proportion of sandstone probably increases towards the basin margins. A high resource potential, certainty level C, for diatomite is assigned to the eastern part of the study area where sandstone and diatomite are exposed. It is unlikely, however, that the quality of undiscovered diatomite will exceed that in the exposed occurrence.

Geothermal Energy

There are no hot springs or other indications of recent or active geothermal systems within the Wildcat Canyon Wilderness Study Area. The proximity of Mickey Springs and the Alvord Valley KGRA and the setting of the study area in the Basin and Range province, however, indicate moderate resource potential, certainty level B, for geothermal energy in the area containing the major arcuate range-bounding fault in the southern part of the study area.

Oil and Gas

The oil and gas resource potential of the entire Wildcat Canyon Wilderness Study Area is low, certainty level B. The Cenozoic volcanic rocks exposed in the area are not source rocks, nor are the few interbedded sedimentary strata. There are no surficial tar or oil seeps, or other evidence of hydrocarbon source beds or reservoirs.

Gas shows have been detected in drill holes that penetrated Neogene strata in relatively small local basins elsewhere in the region (Stewart and Newton, 1965; D.L. Olmstead, personal commun., 1988). Since carbonaceous beds may underlie or be interbedded with volcanic rocks at depth, there is low resource potential for oil and gas in the study area (Fouch, 1983).

Mineral and Energy Resource Potential of the Table Mountain Wilderness Study Area

Gold and Silver

The mineral resource potential is low, certainty level B, for gold and silver in the area containing the large arcuate fault that bounds the south edge of the wilderness study area (fig. 2), on the basis of slight geochemical anomalies detected in stream sediment there. Deposits similar to those found in the Steens-Pueblo mining district conceivably could underlie the wilderness study area (see discussion of gold and silver for Sheepshead Mountains Wilderness Study Area).

Diatomite

Diatomaceous sand and silt exposed in the White Sage Flat area in the southern part of the Table Mountain Wilderness Study Area contain too much carbonate, clay, and quartz to qualify as a diatomite resource. These beds are part of a Pleistocene lake basin whose small size and proximity to range-bounding faults create an unfavorable environment for the accumulation of diatomite resources, in contrast to the late Miocene or Pliocene setting when slightly purer diatomite accumulated in the Wildcat Canyon Wilderness Study Area. Low resource potential, certainty level C, for diatomite is assigned to the White Sage Flat area of the Table Mountain Wilderness Study Area. The area of low resource potential coincides with the Pleistocene lake basin mapped on the south side of the study area.

Geothermal Energy

Mickey Springs, a thermal spring with water temperatures of 160–190 °F and discharge rates of 20 gallons per minute, is located 8 mi south of the Table Mountain Wilderness Study Area at the northeastern edge of the Alvord Valley (Bowen and Peterson, 1970). Hot springs in the Alvord Valley indicate a geothermal system with the potential to produce the equivalent of 200 megawatts of electrical energy over a 30-yr period (Brook and others, 1979). The presence of Mickey Springs and other hot springs and high temperatures detected in wells of the Alvord Valley indicate that the basin is geothermally active, with a resource suitable for direct heat utilization and, perhaps, electrical power production (Peterson and Brown, 1980).

Within the Table Mountain Wilderness Study there are no hot springs or other indications of recent or active geothermal systems. The proximity of the Mickey Springs part of the Alvord Valley KGRA, however, indicates moderate resource potential, certainty level B, for geothermal energy used in direct heating, assuming that some heat from the Mickey Springs system is convected to near the surface in the Table Mountain Wilderness Study Area. The area of moderate resource potential is along the major range-front faults near the west and south edges of the study area, where upwelling of geothermal fluids is most likely.

Oil and Gas

The oil and gas resource potential of the entire Table Mountain Wilderness Study Area is low, certainty level B. The Cenozoic volcanic rocks exposed in the area are not source rocks, nor are the few interbedded sedimentary strata. There are no surficial tar or oil seeps, or other evidence of hydrocarbon source beds or reservoirs (see discussion of oil and gas for Sheepshead Mountains Wilderness Study Area).

Gas shows have been detected in drill holes that penetrated Neogene strata in relatively small local basins elsewhere in the region (Stewart and Newton, 1965; D.L. Olmstead, personal commun., 1988). Since carbonaceous beds may underlie or be interbedded with volcanic rocks at depth, there is a low resource potential for oil and gas in the study area (Fouch, 1983).

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LEVELS OF RESOURCE POTENTIAL

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

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

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

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

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

LEVELS OF CERTAINTY

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

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

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

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

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 RESOURCE POTENTIAL →

LEVEL OF CERTAINTY →

Abstracted with minor modifications from:

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

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RESOURCE/RESERVE CLASSIFICATION

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

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

GEOLOGIC TIME CHART

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

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

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