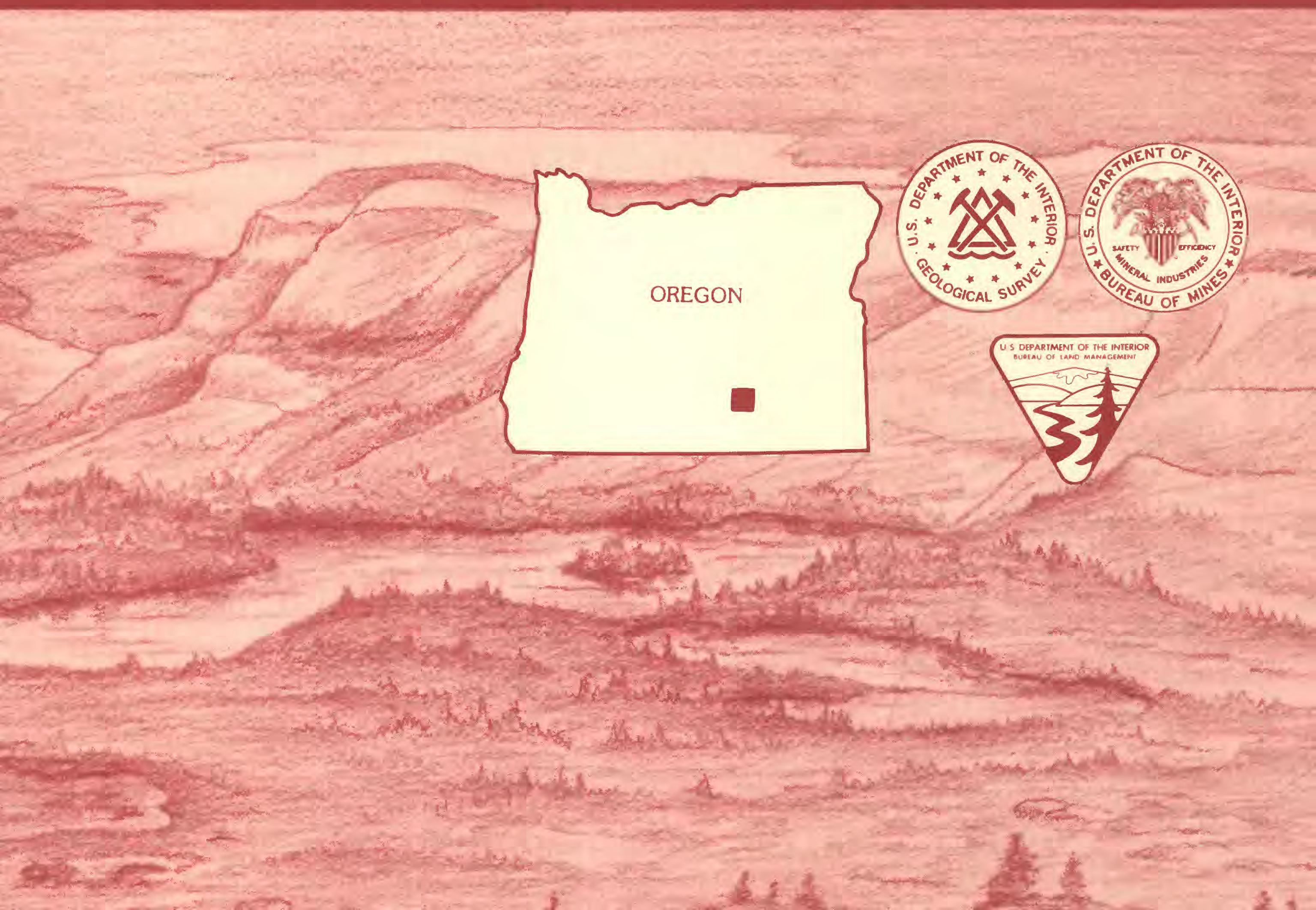
Mineral Resources of the Orejana Canyon Wilderness Study Area, Harney County, Oregon

U.S. GEOLOGICAL SURVEY BULLETIN 1738–B



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Chapter B

Mineral Resources of the Orejana Canyon Wilderness Study Area, Harney County, Oregon

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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

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Area

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of part of the Orejana Canyon Wilderness Study Area (OR-001-078), Harney County, Oregon.

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Mineral Resources of the Orejana Canyon Wilderness Study Area, Harney County, Oregon

By James E. Conrad, Harley D. King, Mark E. Gettings, Michael F. Diggles, *and* Don L. Sawatzky
U.S. Geological Survey

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SUMMARY

Abstract

At the request of the U.S. Bureau of Land Management, approximately 14,800 acres of the Orejana Canyon Wilderness Study Area (OR–001–078) was evaluated for identified 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 Orejana Canyon 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, 35 mi north of Plush, Oreg. Geologic studies, geochemical sampling, and an inventory of mines and prospects indicate low resource potential for gold and silver along the west boundary of the study area and low resource potential for tin in the northwestern part of the study area. The entire study area has low potential for oil and gas resources. There is no geothermal energy or energy mineral resource potential in the study area. The study area contains no identified resources.

Character and Setting

The Orejana Canyon Wilderness Study Area lies on the east side of the northernmost part of Warner Valley about 35 mi north of Plush, Oreg. (fig. 1). Most of the study area is situated on a plateau at an elevation of about 5,000 ft, with gentle topography of low, rolling hills and isolated ridges. Along the west side of the study area, however, Orejana Rim forms a steep west-facing escarpment about 500 ft high at the edge of Warner Valley, and the steep and narrow Orejana Canyon cuts the plateau in the southern and eastern parts of the study area. The climate is semiarid and vegetation consists of sagebrush, desert bunchgrass, and many varieties of wildflowers.

Publication authorized by the Director, U.S. Geological Survey, May 24, 1988.

The study area is underlain by a sequence of basaltic to andesitic lava flows and interbedded tuffaceous sedimentary rocks that are capped by a rhyolite welded tuff of Miocene age (see appendixes for geologic time chart). Faulting related to regional basin and range extension has cut these rocks; the largest of these faults produced the uplift along Orejana Rim. Other minor faults in the study area have displacements of less than 50 ft.

Identified Resources

No metallic or nonmetallic resources were identified within the Orejana Canyon Wilderness Study Area. Investigation into potential resources of diatomite, zeolite, and perlite postulated in a 1985 U.S. Bureau of Land Management study indicated the presence of only minor zeolite, perlite of poor quality, and no diatomite. However, three samples taken of tuffaceous rock units were slightly anomalous in gold, silver, arsenic, lead, antimony, and bismuth. These samples may indicate the presence of low-grade gold and silver mineralization in the area.

Examination of the literature and U.S. Bureau of Land Management and Harney County records contained no evidence of claim or lease activity in the study area. Field examinations also yielded no evidence of mining or claim staking within or adjacent to the area.

Mineral Resource Potential

Geologic, geochemical, and geophysical studies give only slight indications of significant mineralization in the study area. Small, scattered geochemical anomalies, including gold, silver, arsenic, and antimony in rock samples suggest there has been some hydrothermal activity in the area. On this basis, there is low resource potential for gold and silver along the north-south fault paralleling the Orejana Rim escarpment. Anomalous concentrations of tin found in heavy-mineral concentrates from stream sediments

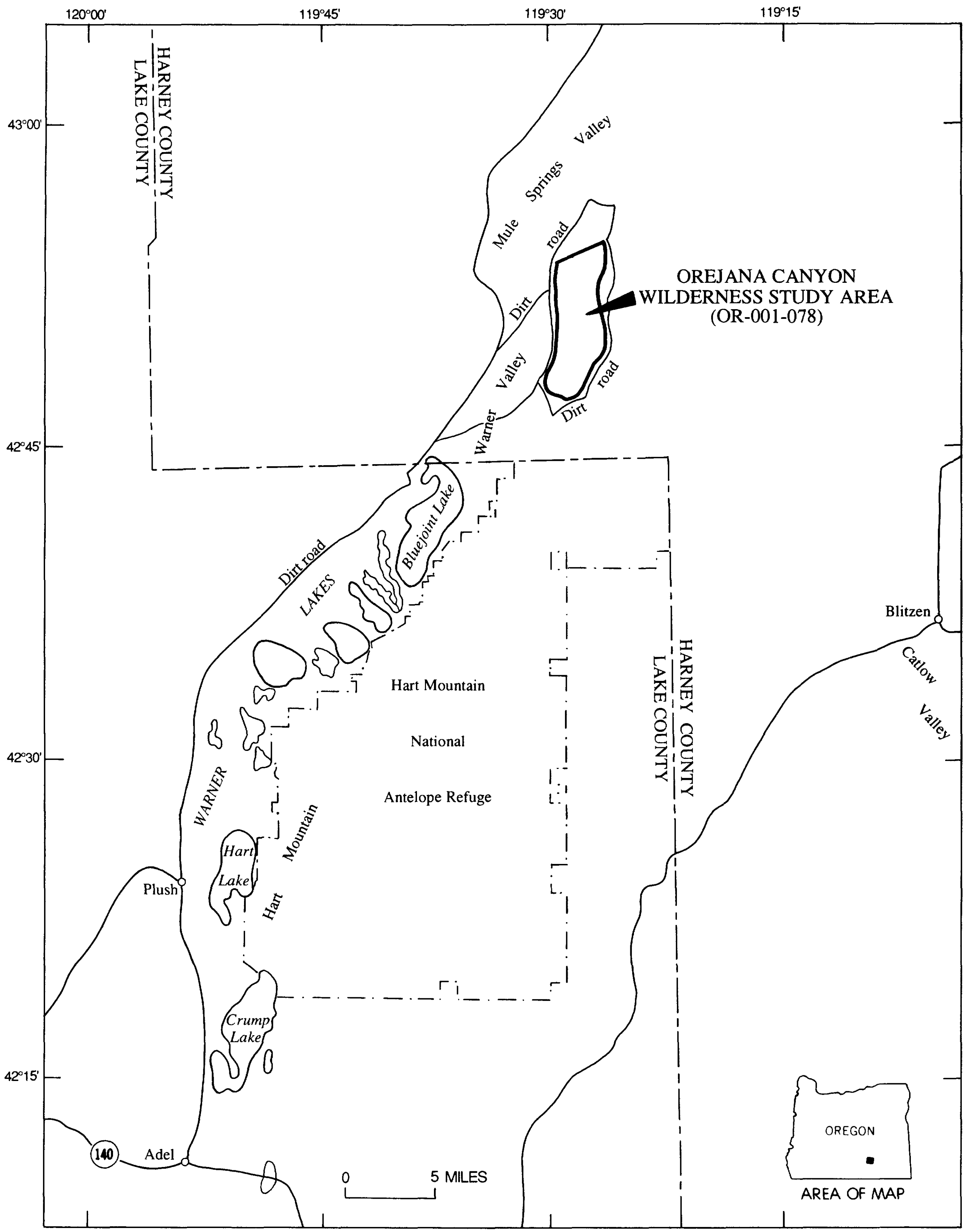

Figure 1. Index map showing location of the Orejana Canyon Wilderness Study Area, Harney County, Oregon.

and one rock sample north of the study area suggest low resource potential for tin at the northwest corner of the study area.

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 a low potential for oil and gas resources. There is no geothermal energy or energy mineral resource potential in the study area.

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 Orejana Canyon Wilderness Study Area is located in south-central Oregon at the north end of Warner Valley (fig. 1). Mineral surveys were requested on 14,800 acres of the wilderness study area by the U.S. Bureau of Land Management. This region is typified by extensive basaltic to andesitic 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 alluviated valleys. Most of the study area is situated on a plateau at an elevation of about 5,000 ft, with gentle topography of low, rolling hills and isolated ridges uplifted along minor faults. Along the west side of the study area, Orejana Rim forms a steep west-facing escarpment about 500 ft high at the edge of Warner Valley, and the steep and narrow Orejana Canyon cuts the plateau in the southern and eastern parts of the study area. The climate is semiarid and vegetation consists of sagebrush, desert bunchgrass, and many varieties of wildflowers.

The study area is located about 35 mi north of the town of Plush, Oreg., and about 5 mi north of the Hart Mountain National Antelope Refuge (fig. 1). The study area is bounded on three sides by dirt roads and jeep trails that can be reached by roads leading north from Plush or from the Hart Mountain National Antelope Refuge. An unimproved jeep trail along the west boundary provides access from Warner Valley below Orejana Rim. Access to the southern and eastern parts of the study area is by maintained dirt roads along the boundaries. Other maintained dirt roads from the north provide access to the northern part of the study area.

Previous and Present Investigations

The study area is included in regional geologic maps at scales of 1:250,000 (Walker and Repenning, 1965) and 1:500,000 (Walker, 1977). Other regional geologic studies in southeastern Oregon include those by Lawrence (1976), McKee and others (1983), and Carlson and Hart (1987). A regional aeromagnetic survey conducted by the U.S. Geological Survey (1972) includes the study area. Information relevant to the study area from this geophysical survey is included in this report.

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 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 of the Western Field Operations Center (WFOC), Spokane, Wash., and consisted of literature search, field work, and report preparation that spanned the years 1985 through 1987. The literature search included an examination of the Harney County 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. Field studies included a search for evidence of mining activity and mineralized sites within the area studied.

Much of the field work consisted of examination of tuff and rhyolite beds for presence of diatomite, zeolite, and perlite, which a previous study conducted by the U.S. Bureau of Land Management (1985) suggested was present in the study area. Sixteen rock samples were taken during the course of study, 11 from rhyolite flows and 5 from tuffaceous beds.

Nine samples were analyzed for 18 metallic elements using atomic-absorption spectroscopy (Benjamin, 1987). All tuffaceous samples were examined for diatomite using

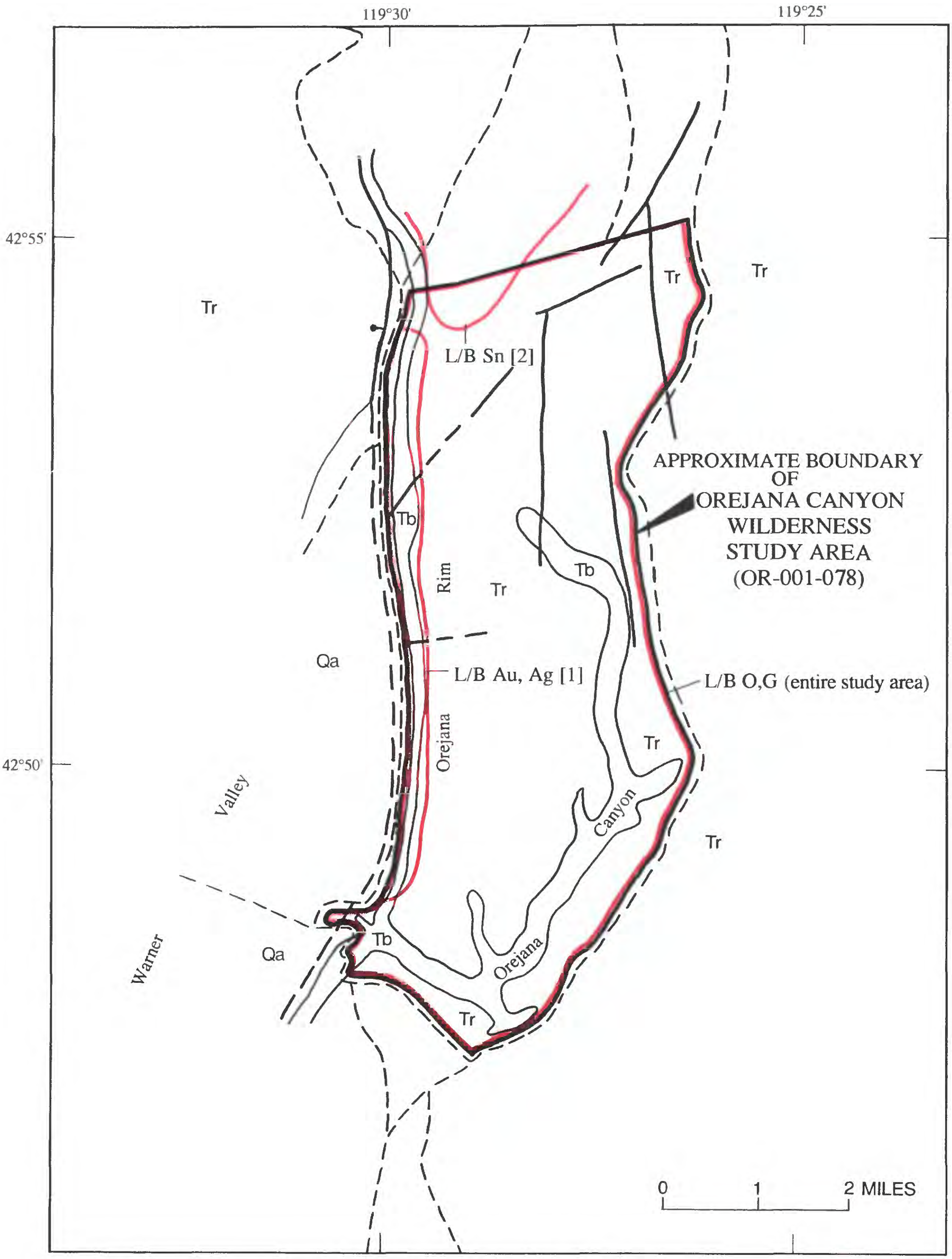

Figure 2. Mineral resource potential and generalized geology of the Orejana Canyon Wilderness Study Area, Harney County, Oregon.

EXPLANATION

[ ] Area having low resource potential for specified commodity (L); data only suggest level of potential (B)

Commodities

Ag — Silver
Au — Gold
Sn — Tin
O,G — Oil and gas

[ ] Deposit types

1 — Epithermal or hot-spring gold-silver low-grade bulk-mineable
2 — Rhyolite-hosted tin

Correlation of map units

Qa — Quaternary — Cenozoic
Tr, Tb — Tertiary — Cenozoic

Description of map units

Qa — Alluvium, colluvium, and talus (Holocene or Pleistocene)—Mostly stream sand and gravel, fanglomerate, and aeolian and lacustrine sediments

Tr — Rhyolite (Miocene)—Rhyolite welded tuff. Contains phenocrysts of quartz, sanidine, and plagioclase in a eutaxitic groundmass of devitrified glass shards. Abundant lithophysae in the lower two-thirds of the flow, commonly weathering out to give the rock a "swiss cheese" appearance

Tb — Basalt flows and tuffaceous sedimentary rocks (Miocene)—Includes basalt flows and flow breccia, air-fall tuff, and associated sedimentary rocks

Contact
Normal fault—Bar and ball on downthrown side; dashed where approximately located
Dirt road or jeep trail

Figure 2. Continued.

a petrographic microscope; the same samples were also tested at WFOC for zeolite content by the ion exchange capability method (Helfferich, 1964). Three zeolite samples were sent to the Cominco Exploration Research Laboratory (Vancouver, B.C.) for further testing. Additionally, eight rhyolite samples were examined petrographically for perlite.

Further information concerning analytical and other testing methodology, detection limits, and results is 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 Gerilyn Andrews and Steve Smith. The U.S. Bureau of Mines author was assisted in the field by Terry Neumann and Spencee Willett of WFOC. Appreciation is also extended to Douglas Troutman (Lakeview, Oreg., U.S. Bureau of Land Management) for information about road conditions and mineral activity in and around the area studied.

APPRAISAL OF IDENTIFIED RESOURCES

By David A. Benjamin
U.S. Bureau of Mines

Mines and Prospects, Mining Claims, and Leases

Examination of the historical literature and county and U.S. Bureau of Land Management records indicates that no claim or lease activity has ever taken place in the study area or within a mile of the study area. Furthermore, field investigation failed to identify any evidence of exploration or mining activities.

Reserves and Identified Resources

No reserves or resources of either metallic or nonmetallic commodities were identified in the Orejana Canyon Wilderness Study Area. A study by the Bureau of Land Management (1985) suggests the existence of diatomite, zeolite, and perlite; however, the present study did not confirm the presence of any diatomite and only confirmed very minor amounts of zeolite. Perlite textures were poorly developed in some lava flows, and the material did not approach commercial quality.

Assay results indicate that three tuff samples are slightly anomalous in gold, silver, arsenic, lead, antimony, and bismuth. This could be an indicator of low-grade gold mineralization.

Recommendations for Further Study

No further work is recommended on diatomite, zeolite, and perlite. The gold-silver-antimony-lead-bismuth-arsenic anomaly indicated by the three slightly anomalous samples may warrant additional geologic mapping and sampling.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By James E. Conrad, Harley D. King, Mark E. Gettings, Michael F. Diggles, *and* Don L. Sawatzky
U.S. Geological Survey

Geology

The Orejana Canyon Wilderness Study Area is in a transitional zone between the Basin and Range and Columbia Plateaus physiogeographic provinces. Extensive flood basalts and associated interbedded air-fall tuffs and sedimentary rocks of Miocene age underlie most of the region. North-south-trending basin and range faults have cut these rocks, producing the north-south-trending mountain blocks and intervening alluvium-filled valleys. The study area lies between the Brothers and Eugene-Denio northwest-trending fault zones, interpreted as boundary zones between basin and range extension to the south and unextended terrane of the Columbia Plateaus to the north (Lawrence, 1976).

At least two periods of volcanism are recorded within the study area. The older period produced a sequence of nearly flat-lying basalt flows and interbedded tuffaceous sedimentary rocks. The base of this sequence is not exposed, but nearly 500 ft of section is present in the study area. The top of this sequence is marked by an erosional unconformity that dips about 5° to the south. A rhyolitic welded ash-flow tuff as much as 100 ft thick lies above the unconformity and forms a cap over the older volcanic and sedimentary rocks.

Rocks in the lower volcanic sequence consist of three separate basaltic to andesitic lava-flow units interbedded with air-fall tuffs and tuffaceous sedimentary rocks. The lava-flow units are about 30 to 70 ft thick and are typically black, aphanitic, vesicular to nonvesicular and may be composed of one or several individual flows. Basaltic flow breccias are present in the middle part of this unit, consisting of basaltic blocks 0.5 to 20 in. across in a matrix of ropy basalt.

The upper volcanic unit consists of rhyolitic welded tuff that underlies the plateau and forms a near-vertical cliff as much as 100 ft high at the top of Orejana Rim and rimming Orejana Canyon. Widely spaced vertical joints in this unit are responsible for the unusual topography in the southwestern part of the study area beneath Orejana Rim, where hundreds of huge blocks as much as 50 ft across have broken off and litter the slopes below the rim. The rhyolite tuff is as much as 100 ft thick, has a basal surge zone about 5 ft thick, and a basal vitrophere of black obsidian about 3 ft thick. The remaining part of the unit consists of a welded zone of vitric ash-flow tuff containing collapsed pumice fragments and phenocrysts of quartz, sanidine, and plagioclase. All but the upper part of this welded zone contains abundant lithophysae about 1 in. across, which in many places have weathered out to give the rock a "swiss cheese" appearance. This tuff probably correlates with tuffs exposed near Harney Basin, about 30 mi to the north, which have been dated at about 8 Ma (Fiebelkorn and others, 1982).

Geochemical Studies

A reconnaissance geochemical survey was conducted in the Orejana Canyon Wilderness Study Area in the summer of 1986. Minus-80-mesh stream sediments, nonmagnetic heavy-mineral concentrates of stream sediments, and rocks were used as the sample media in this survey. Twenty-two minus-80-mesh stream-sediment, 22 nonmagnetic heavy-mineral-concentrate, and two rock samples were collected from 22 sites. The stream-sediment samples and the stream sediments from which the concentrates were derived were taken from the active alluvium in the stream channels.

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, providing mineralization processes have 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.

One of the rock samples appeared fresh and unaltered and was collected to provide information on geochemical background values. The other rock sample appeared altered and possibly mineralized; this was collected to determine the suite of elements associated with the observed alteration or mineralization.

Rock samples were crushed and pulverized to less than 80-mesh grain size prior to analysis. 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 produced by panning minus-10-mesh stream sediment to remove most of the quartz, feldspar, organic material, and clay-sized material. Bromoform (specific gravity, 2.86) was then used to remove light mineral grains from the panned concentrate. The resultant heavy mineral concentrate was separated by use of an isodynamic magnetic separator into three fractions: a magnetic fraction, chiefly magnetite, an intermediately magnetic fraction consisting largely of mafic rock-forming minerals, and a nonmagnetic fraction, which is composed dominantly of light-colored rock-forming 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 reference material 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). Rock and stream-sediment samples were also analyzed by atomic-absorption spectrometry for certain elements of special interest or which have high lower limits of determination by emission spectrography. Antimony, arsenic, bismuth, cadmium, and zinc were analyzed by the method of O'Leary and Viets (1986), gold by the method of Thompson and others (1968), and mercury by the method described in Crock and others (1987).

Anomalous values of tin (700–2,000 parts per million (ppm)) were found in five nonmagnetic heavy-mineral-concentrate samples collected in the north end of the sampled area, just north of the study area boundary. Microscopic examination of the concentrates revealed that the high tin values were due to the presence of several grains of wood tin (cassiterite) in the samples. These grains of wood tin possibly eroded from fractures in the rhyolitic ash-flow tuff that underlies those drainages north of the study area. One rock sample was collected from an altered zone in this area and contained slightly anomalous values of tin (10 ppm) and lead (50 ppm).

Slightly anomalous values of mercury (0.18–0.38 ppm) were found in four stream-sediment samples, three from the south end of the study area and one from about 1.7 mi north of the study area. The drainage area of the latter site is outside of the study area. The mercury detected in the samples may have moved upward along fractures in volcanic rocks within the drainage areas of the sample sites and have been adsorbed on mineral grains that were later eroded and incorporated into the stream sediment. These anomalous values apparently do not indicate significantly mineralized rock at the surface, but may reflect rock enriched in mercury or other metals, including gold, at some unknown depth. It is possible that the anomalous mercury values are not related to significantly mineralized rock. These slightly anomalous mercury values are not interpreted to be associated with anomalies of other elements discussed in this report.

Geophysical Studies

An aeromagnetic survey including the Orejana Canyon Wilderness Study Area was flown and compiled in 1973 under U.S. Geological Survey contract (U.S. Geological Survey, 1972). Total-field magnetic data were collected in analog form along east-west flight lines spaced approximately 2 mi apart at a constant barometric altitude of 9,000 ft. Corrections were applied to the data to compensate for regional and diurnal variations of the earth's magnetic field to yield a digital residual magnetic anomaly data set. An aeromagnetic map of the wilderness study area was prepared at a contour interval of 50 nanoteslas (nT) from the digitized analog data for comparison with geologic and topographic maps.

Within and near the study area, the total relief of the residual magnetic anomaly field is only about 150 nT, in the form of an east-west-trending ridgelike high through the approximate center of the study area. Magnetic anomalies are very smooth and appear to be due to sources 1 mi or more below the observation plane, that is, at least 0.2 mi below the ground surface. Within the study area, anomaly amplitude does correlate somewhat with topography, but topography appears to produce only a small perturbation of the anomaly shapes. All anomalies observed within the study area are parts of regional anomalies extending well beyond the boundaries of the study area. The trends of the gradients of these anomalies are parallel to and in many cases coincident with mapped fault zones along northeast, northwest, and north-northwest trends. The sources of the magnetic anomalies are inferred to be faulted blocks of magnetic basement, and no indications of near-surface structures were observed in the magnetic data, both because of the large terrain clearance (0.75–1.0 mi) of the data observation level and the relatively nonmagnetic character of the surface rocks.

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

Linear features of every orientation are well expressed on the surface in southeastern Oregon, except in terrains underlain by volcanic rocks. Areas may have preferred trends related to faults, if locally important, or to rock joint systems. The study area has no prominent linear features within it. However, linear features in the region around the study area have two prominent trends. The dominant trend is N. 20° W., but linear features with this trend are concentrated north and west of the study area. Linear features with the second trend, N. 20° E., lie to the northwest of the study area.

Mineral and Energy Resource Potential

Geologic, geochemical, and geophysical studies suggest that only minor mineralization may have occurred in the study area. Field examination of outcrops did not disclose evidence of extensive or pervasive alteration associated with mineralization. Geochemical studies, however, show some indications of hydrothermal activity that may be associated with mineralization. Three rock samples, taken by the U.S. Bureau of Mines from exposures along the Orejana Rim escarpment, had slightly anomalous concentrations of gold, silver, lead, bismuth, arsenic, and antimony. The north-south-trending fault that formed the Orejana Rim escarpment may have served as a pathway for metal-bearing hydrothermal fluids. These anomalies may reflect low-grade gold-silver mineralization, perhaps in epithermal veins or in hot-spring gold-silver deposits (Berger, 1986). There is low potential for gold and silver resources, certainty level B, in low-grade, bulk-mineable deposits along the west side of the study area (fig. 2).

Anomalous concentrations of tin, produced by wood tin (cassiterite) in five heavy mineral concentrates from stream sediments, and an anomalous tin concentration in one rock sample, were found in samples collected from drainages underlain by a rhyolite ash-flow tuff just north of the study area. A deposit type suggested by this tin anomaly is the rhyolite-hosted tin deposit (Reed and others, 1986). The abundant lithophysae in the welded ash-flow tuff suggest late-stage, vapor-phase alteration that may have remobilized and concentrated tin. There is low resource potential for tin, certainty level B, mostly north of the study area, but including the northwest corner of the study area.

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, however, would most likely have driven off any preexisting hydrocarbons. The study area has a low potential for oil and gas resources, certainty level B (Fouch, 1983).

There are no hot springs or other indications of geothermal activity in or near the study area (Bliss, 1983), so there is no geothermal resource potential in the study area, certainty level D. No diatomite or lacustrine rocks of any kind were observed in the bedrock underlying the study area, so there is no potential for undiscovered resources of diatomite, certainty level D. Although minor zeolite occurrences and poorly developed perlite occurrences were noted in the Orejana Canyon study area, these occurrences do not constitute resources, and there is no potential for undiscovered resources of these commodities, with a certainty level of D.

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LEVELS OF RESOURCE POTENTIAL

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

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

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

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

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

LEVELS OF CERTAINTY

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

LEVEL OF RESOURCE POTENTIAL →

A	B	C	D
U/A	H/B HIGH POTENTIAL	H/C HIGH POTENTIAL	H/D HIGH POTENTIAL
UNKNOWN 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:

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

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

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