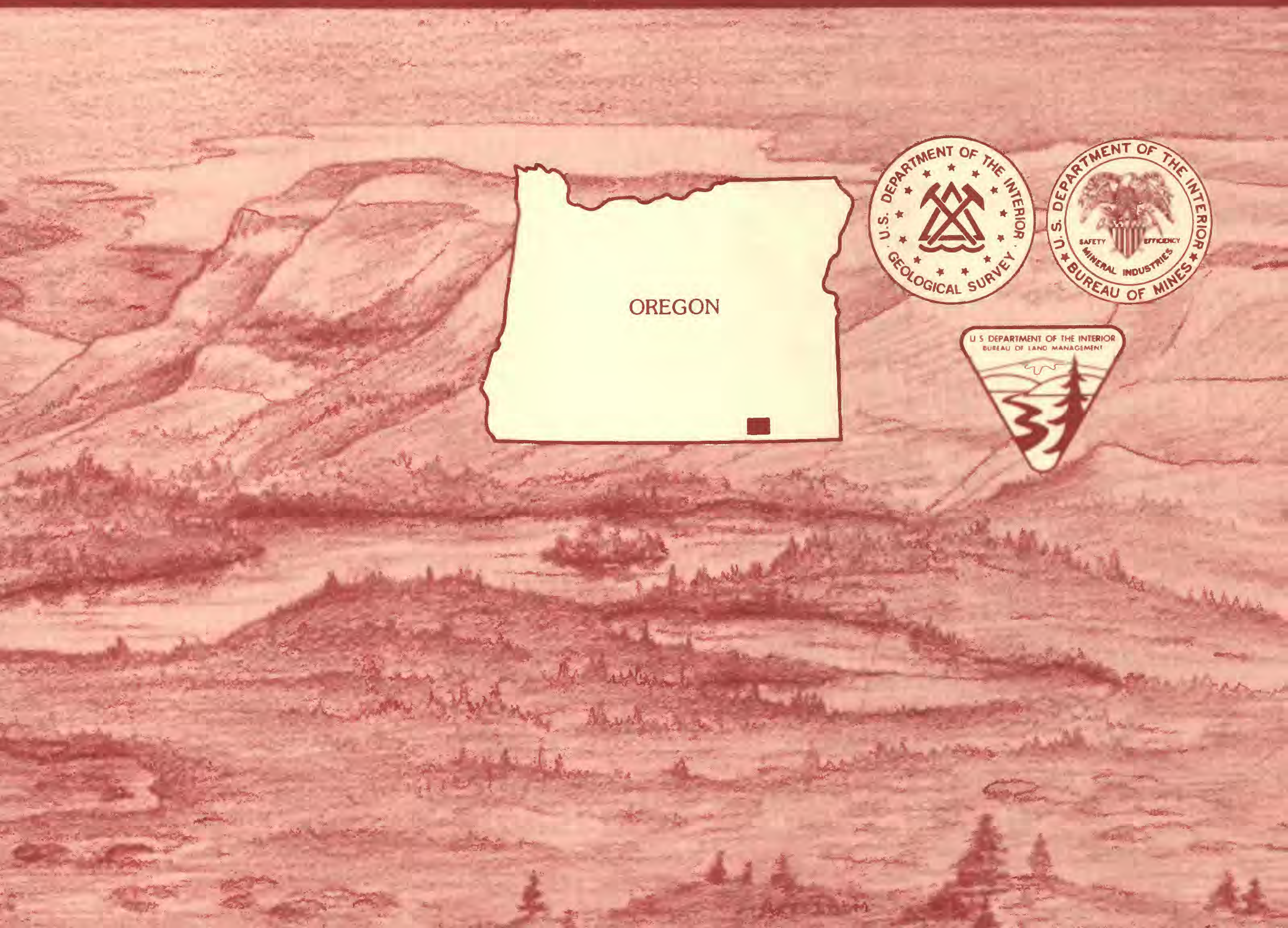
Mineral Resources of the Rincon Wilderness Study Area, Harney County, Oregon

U.S. GEOLOGICAL SURVEY BULLETIN 1740–E



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Chapter E

Mineral Resources of the Rincon Wilderness Study Area, Harney County, Oregon

By DEAN B. VANDER MEULEN, DONALD PLOUFF, and HARLEY D. KING
U.S. Geological Survey

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U.S. GEOLOGICAL SURVEY BULLETIN 1740

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
STEENS MOUNTAIN–RINCON REGION, 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 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 Rincon Wilderness Study Area (OR–002–082), Harney County, Oregon.

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Mineral Resources of the Rincon Wilderness Study Area, Harney County, Oregon

By Dean B. Vander Meulen, Donald Plouff, *and* Harley D. King
U.S. Geological Survey

Ronald T. Mayerle *and* Richard L. Rains
U.S. Bureau of Mines

SUMMARY

Abstract

At the request of the U.S. Bureau of Land Management, the U.S. Geological Survey and the U.S. Bureau of Mines conducted field studies of 20,500 acres of the Rincon Wilderness Study Area. The Rincon Wilderness Study Area (OR–002–082) is located between Catlow Valley and the Pueblo Mountains in southeastern Oregon. In this report, the area studied is referred to as the "wilderness study area," or simply the "study area." Field work was conducted by the U.S. Geological Survey during 1986 and 1987, and by the U.S. Bureau of Mines during 1986, to evaluate the identified mineral resources (known) and the mineral resource potential (undiscovered) of the study area.

No mineral resources were identified in the study area. However, the study indicates moderate potential for silver resources in a rhyolite ash-flow tuff exposed near the central part of the study area and high potential for sand and gravel resources in lake shoreline deposits along the northwest boundary of the study area. The entire study area has low potential for geothermal resources and no potential for oil and gas.

Character and Setting

The Rincon Wilderness Study Area is located along Catlow Rim approximately 90 mi south of Burns, Oregon, and 10 mi west of Fields, Oregon (fig. 1). Catlow Rim is a fault scarp that rises 1,000 to 1,900 ft above Catlow Valley and forms the entire length of the impressive 60-mi-long east valley wall. A large displacement fault at the base of the escarpment is the dominant geologic structure in the region and forms the west margin of the 30- by 90-mi, north-trending Steens-Pueblo Mountains fault block. The area east of the rim is characterized by a gently southwest-tilted dip slope cut by several west-flowing creeks (fig. 1).

Middle Miocene-age basalt flows form the 1,600-ft-high Catlow Rim escarpment and are the oldest rocks exposed in the study area. The middle Miocene ranges from 11.2 to 16.6 million years before present, or Ma; see appendixes for geologic time chart. A sequence of andesite flows, tuffaceous sedimentary rocks, and ash-flow tuffs overlies the basalt flows. The stratigraphic section is capped by younger andesite flows of late Miocene and Pliocene age (Walker and Repenning, 1965). The western part of the study area extends into Catlow Valley, a broad, irregular-shaped graben. Pleistocene shoreline deposits and Holocene dunes are exposed in the valley.

Identified Resources

No mines, claims, or prospects were found, and no mineral or energy resources were identified within or adjacent to the study area.

Mineral Resource Potential

A rhyolite ash-flow tuff near the central part of the study area (fig. 2) has moderate potential for silver resources. One unaltered sample of this tuff contains

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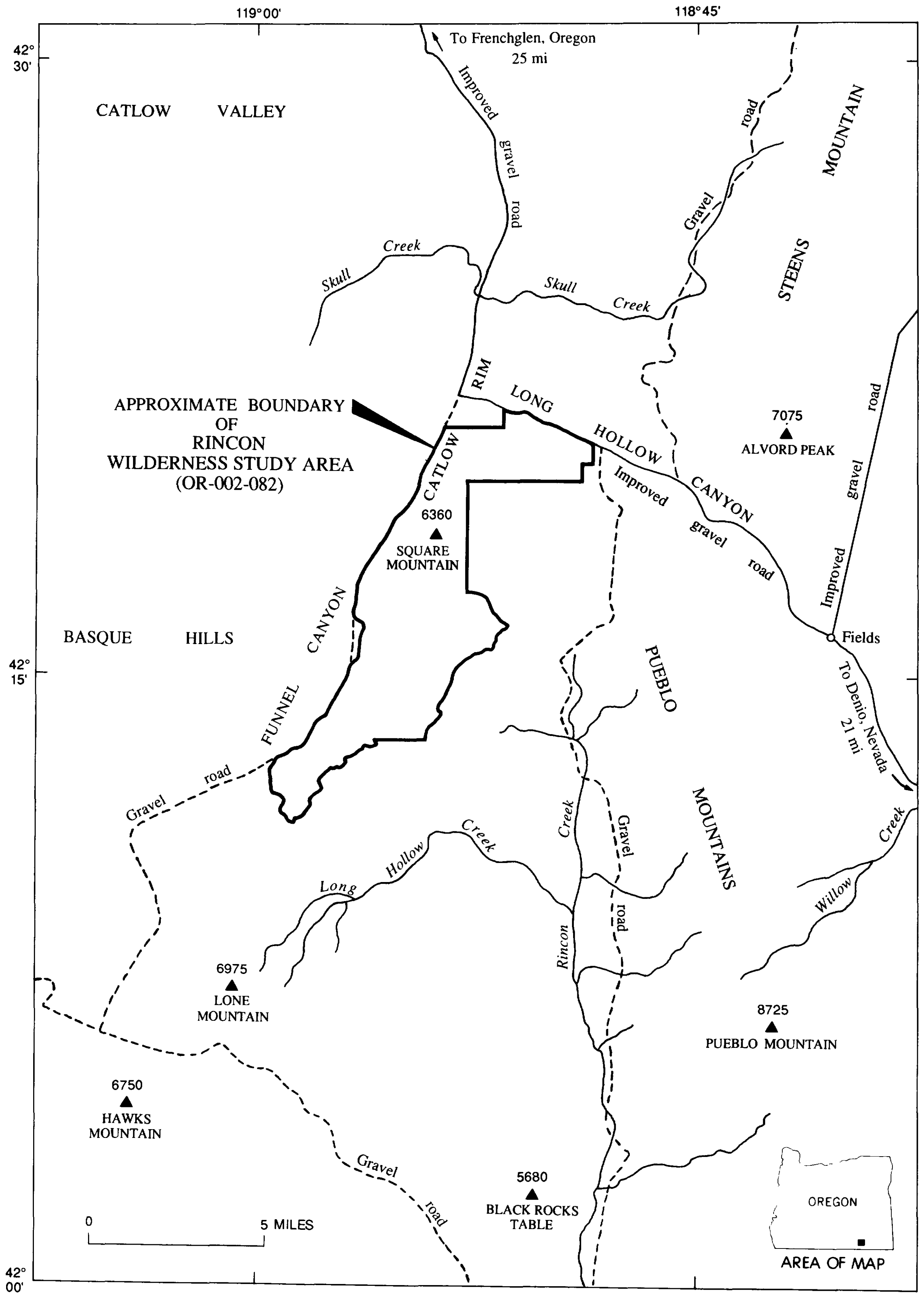

Figure 1. Index map showing location of the Rincon Wilderness Study Area, Harney County, Oregon.

anomalously high silver, and a stream-sediment sample collected from the basin containing the tuff also contains anomalous amounts of silver.

Shoreline sand and gravel deposits form extensive terraces along the base of Catlow Rim in the western part of the study area (fig. 2). Shoreline gravel deposits near the northwest boundary of the study area have been utilized for aggregate; therefore, the northwestern part of the wilderness study area has high potential for sand and gravel resources.

Fault zones that cross parts of the study area may be associated with geothermal waters at depth. Hot springs issue from similar fault zones 10 mi east and 20 mi south of the study area. The entire study area has low potential for geothermal resources and no potential for oil and gas.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management and is a joint effort by the U.S. Geological Survey and U.S. Bureau of Mines. An introduction to the wilderness review process, mineral survey methods, and agency responsibilities was provided by Beikman and others (1983). The U.S. Bureau of Mines evaluates identified resources at individual mines and known mineralized areas by collecting data on current and past mining activities and through field examination of mines, prospects, claims, and mineralized areas. Identified resources are classified according to the system modified from that described by McKelvey (1972) and the U.S. Bureau of Mines and U.S. Geological Survey (1980). Studies by the U.S. Geological Survey are designed to provide a reasonable scientific basis for assessing the potential for undiscovered mineral resources by determining geologic units and structures, possible environments of mineral deposition, presence of geochemical and geophysical anomalies, and applicable ore-deposit models. Mineral assessment methodology and terminology as they apply to these surveys were discussed by Goudarzi (1984). See appendixes for definition of levels of mineral resource potential, certainty of assessment, and resource/reserve classification.

Area Description

The area studied encompasses 20,500 acres in the northern Basin and Range physiographic province of southeastern Oregon. It is located along the southeast side of Catlow Valley (fig. 1) approximately 35 mi south of Frenchglen, Oregon. The study area is accessible by an improved gravel road that parallels the west side of Catlow Rim and by several unimproved dirt roads and jeep trails that approach the study area from the north and south. Maximum elevation in the study area is approximately 6,400 ft above sea level at the crest of Square Mountain (fig. 1); minimum elevation is about 4,500 ft on Catlow Valley floor. The climate is semiarid, and the vegetation is sparse with sage brush and grasses dominant at all elevations. Parts of the study area are currently used for cattle grazing.

Previous and Present Investigations

Previous geologic investigations that included the study area were reconnaissance geologic mapping of the Adel 1° by 2° quadrangle by Walker and Repenning (1965), an aeromagnetic survey by the U.S. Geological Survey (1972), and an aerial radiometric and magnetic survey by Geodata International, Inc. (1980). The U.S. Geological Survey conducted a combined geologic, geochemical, and geophysical survey of the wilderness study area during 1986 and 1987. Field investigations focused on correlating geochemical and geophysical anomalies with rock units and geologic structures.

The U.S. Bureau of Mines investigation consisted of prefield and field studies (Mayerle and Rains, 1987). During the prefield study, mining-related data were examined. These data were gathered from the libraries and records of the U.S. Bureau of Mines and the U.S. Bureau of Land Management; state, county, and other government agencies; and private sources. Field studies included a ground reconnaissance survey to search for evidence of possible mineralized areas and unrecorded mining activity. Additional information is available from the U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Avenue, Spokane, WA 99202.

APPRAISAL OF IDENTIFIED RESOURCES

By Ronald T. Mayerle *and* Richard L. Rains
U.S. Bureau of Mines

Mines, Prospects, Claims, and Mineralized Areas

No records of mining or mineral exploration were found in the literature, nor did a ground search reveal any evidence of mining-related activity within the study area.

The nearest mining district, Pueblo-Steens, roughly parallels and extends to within 4 mi of the east boundary of the study area. The district is located in a mineralized belt that extends 40 mi north-northeast along the east escarpment of Pueblo and Steens Mountains. In the district, small amounts of mercury, gold, and copper have been mined from vein and replacement deposits in silicified zones

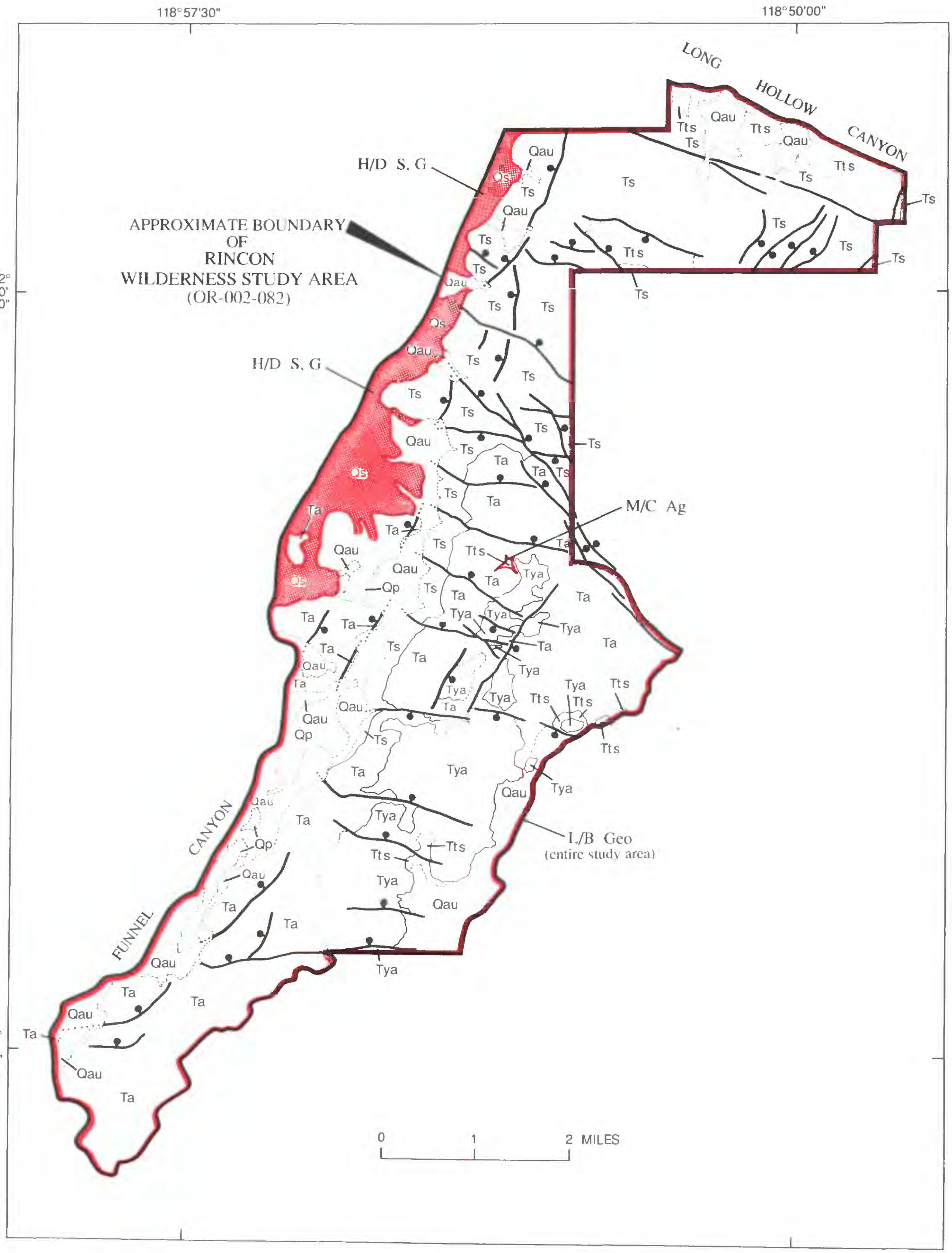

Figure 2. Mineral resource potential of the Rincon Wilderness Study Area, Harney County, Oregon.

(Munts and Willett, 1987; L.E. Esparza and T.J. Peters, written commun., 1987). Other metal occurrences in the Pueblo-Steens mining district include uranium in veins; gold, copper, molybdenum, and mercury, possibly associated with a multi-phase intrusive felsic complex; and epithermal disseminated gold in silicified zones (Roback and others, 1987). Occurrences of perlite, zeolite, diatomite, dimension and decorative stone, agate, and chalcedony gemstones are also known. Claims in the district are being explored for epithermal disseminated gold deposits by the Freeport Minerals Corporation (Mayerle and Rains, 1987).

Appraisal of Mineral Resources

No mineral or energy resources or occurrences were identified in or adjacent to the Rincon Wilderness Study Area. One of seven alluvial samples taken from the major drainages in the study area contains $0.07 gold per cubic yard (calculated using a gold price of $400.00 per troy ounce). That sample was collected from a stream bed along the south boundary. The gold was probably derived from a source outside of the study area. Presently, gold concentrations such as this are of economic interest as indicators but not as gold-bearing gravel deposits to be mined. Geological environments similar to those associated with mineralization in the Pueblo-Steens mining district are not recognized in the Rincon Wilderness Study Area.

EXPLANATION

Area with high resource potential (H)

Area with moderate resource potential (M)

Area with low resource potential (L)

Levels of certainty of assessment

B	Data only suggest level of potential
C	Data give good indication of level of potential
D	Data clearly define level of potential

Commodities

Ag	Silver
S,G	Sand and gravel
Geo	Geothermal

Geologic map units

Qp	Playa deposits and sand dunes (Quaternary)
Qau	Alluvium, colluvium, and talus deposits; undifferentiated (Quaternary)
Qs	Shoreline deposits (Quaternary)
Tya	Younger andesite flows (Tertiary)
Tts	Ash-flow tuff and sedimentary rocks (Tertiary)—Includes Devine Canyon Ash-flow Tuff, tuff of Oregon Canyon, and tuff of Trout Creek Mountains
Ta	Andesite flows (Tertiary)
Ts	Steens Basalt (Tertiary)

Contact—Dotted where approximate

Fault—Dotted where concealed; ball and bar on downthrown side

Figure 2. Continued.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Dean B. Vander Meulen, Donald Plouff, *and* Harley D. King
U.S. Geological Survey

Geology

The oldest rock unit exposed in the Rincon Wilderness Study Area is the middle Miocene Steens Basalt (Piper and others, 1939; Baksi and others, 1967), which consists of a thick, chemically homogeneous sequence of basalt flows. The base of the Steens Basalt is not exposed in the study area. Steens Basalt has a minimum thickness of at least 1,600 ft in the northern part of the study area along Catlow Rim escarpment. The basalt flows, which are commonly 20 to 40 ft thick, underlie most of the northern part of the study area. The flows form a well-exposed, laterally continuous sequence along the northern part of the escarpment; offsets produced by northwest-trending normal faults are visible along the escarpment.

The Steens Basalt dips 2° to 8° southeast and is completely overlain by a sequence of andesite flows in the southern part of the study area. This relation is best revealed along Catlow Rim escarpment near the central part of the study area, where andesite flows form a massive 300-ft-thick capping unit that is faulted against and overlies Steens Basalt. In the southern part of the study area along Funnel Canyon (fig. 2), the Steens Basalt dips southeast below Catlow Rim and is concealed by the andesite flows and Quaternary valley-fill sediment. In this area, the sequence of andesite flows is about 800 ft thick and forms the entire thickness of the Catlow Rim escarpment. The andesite unit varies from platy and flow foliated to vesicular and nonfoliated. In the west-central part of the study area along Catlow Rim, the andesite unit thickens, loses most of its flow characteristics, and grades into massive porphyritic rock. The thickness suggests that either a source vent for the andesite was located nearby, or that the area was a paleodepression where andesite lavas ponded and cooled slowly.

Tuffaceous sedimentary rocks and a partly welded to nonwelded lithic ash-flow tuff overlie the andesite flows near the east boundary of the study area. This same lithic tuff is exposed along the west dip slope of Pueblo Mountains, 10 mi southeast of the study area (Tower, 1972;

Roback and others, 1987). Younger andesite flows cap both the lithic tuff and sedimentary rocks near the east boundary of the study area. The younger andesite flows are thicker and more extensive near the central part of the study area, where they fill a small west-trending graben.

In the northern part of the study area, the Steens Basalt is unconformably overlain by sedimentary rocks and two middle Miocene rhyolite ash-flow tuffs of the McDermitt volcanic field, dated at 15 to 16.1 Ma (Rytuba and McKee, 1984). The tuff of Oregon Canyon and tuff of Trout Creek Mountains (Rytuba and others, 1983) form a 40- to 60-ft-thick topographic bench along the south side of Long Hollow Canyon (fig. 2). A third ash-flow tuff, which is 10 to 15 ft thick, is concordant with and directly overlies the McDermitt tuffs. Whole-rock and trace-element data indicate that this overlying tuff is correlative with part of the Devine Canyon Ash-flow Tuff (Greene, 1973; Hildreth, 1981), dated at 9.2 Ma (Walker, 1979). The combined thickness of the tuff of Oregon Canyon and Devine Canyon Ash-flow Tuff exceeds 160 ft where they fill a small graben 1.5 mi south of Long Hollow Canyon. These two tuffs are locally included in the Tertiary ash-flow tuff and sedimentary rocks unit (fig 2).

Isolated exposures of Devine Canyon Ash-flow Tuff are also present in the eastern and central parts of the study area. Near the east boundary of the study area, exposures of the welded tuff typically form narrow meandering ridges. These meandering ridges represent paleostream channels that were filled by the welded tuff and later exposed by preferential erosion of the surrounding rock.

All four tuffs exposed in the study area represent the distal margins of caldera-forming ash-flow tuff eruptions. The tuff of Oregon Canyon was erupted from the Washburn caldera, located about 45 mi east-southeast of the study area. The tuff of Trout Creek Mountains was erupted from the Pueblo caldera, 8 mi east of the study area (Rytuba and McKee, 1984). The Devine Canyon Ash-flow Tuff erupted from a caldera located in the Harney Basin, about 70 mi north of the study area (Walker, 1970; Greene, 1973).

West of Catlow Rim is Catlow Valley, a large, irregular-shaped graben formed by basin-and-range extensional tectonism. During the Pleistocene, the valley was filled by Catlow Lake. In the study area, wave-cut benches and shoreline deposits that formed during several lake levels are perched on Catlow Rim escarpment. The highest shoreline deposit is 4,795 ft above sea level, about 260 ft above the present valley floor. At least five ancient shorelines are exposed along the west face of the escarpment. The shorelines are delineated by beach, bar, and spit deposits and by wave-cut benches. Deltaic deposits also form part of the ancient shorelines, where larger streams entered Catlow Lake. Shoreline deposits consist of partly sorted to well-sorted sand and gravel. A shoreline bar near the central part of the study area has an estimated maximum thickness of 50 ft.

Holocene alluvium, colluvium, and talus deposits cover parts of the Catlow Rim escarpment (fig. 2). Along the base of the escarpment, shoreline deposits are partly concealed by these deposits. Streams draining the western part of the study area have breached and eroded some of the shoreline benches and bars; in other locations, alluvial stream deposits have buried the shorelines. In the westernmost part of the study area, playa deposits and sand dunes are common along the valley floor. Studies by Mehringer and Wigand (1984) indicate that dunes 4 mi north of the study area migrated several times during the Holocene. Two substantial air-fall tuffs from Mount Mazama, dated at 0.007 Ma (Mehringer and Wigand, 1984), are preserved in the dunes. Ancient artifacts are also preserved in the dunes.

Three different fault sets were mapped in the Rincon Wilderness Study Area. The most conspicuous set is the northeast-trending range-front fault zone and parallel normal faults, along which basin-and-range extensional tectonism formed the prominent Catlow Rim escarpment. A second set of normal faults trends N. 75° W. and forms several small horst and graben structures that displace the rim perpendicular to the range-front fault. Long Hollow Canyon is the largest northwest-striking graben, trending parallel to the north boundary of the study area (fig. 2). Extensional forces trending parallel to Catlow Rim escarpment, about 90° to the major extension in the region, formed these horst and graben structures. A third fault set is expressed as a series of well-preserved N. 45° W.-striking en echelon fault scarps that parallel the east-central boundary of the study area. These northwest-striking fault scarps form a linear fault zone less than 0.5 mi wide that extends into the north-central part of the study area (fig. 2). Some of the N. 75° W.-striking faults along the north-central part of Catlow Rim are truncated by this fault zone.

Geochemical Studies

In 1986–87, the U.S. Geological Survey conducted a reconnaissance geochemical study of the Rincon Wilderness Study Area. The study included the collection and analysis of 11 rock samples, 22 stream-sediment samples, and 21 nonmagnetic heavy-mineral concentrates of stream sediments. Stream-sediment samples, and stream sediments from which the concentrates were derived, were collected from active alluvium in stream channels.

Stream sediments represent composites of rock and soil exposed upstream from sample sites. Stream-sediment samples are useful in identifying basins that contain concentrations of elements possibly related to mineralized rock. 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. Selective concentration of minerals permits determination of some elements that are not easily detected in bulk stream-sediment samples. Most rock samples appeared fresh and unaltered and were collected to provide information on geochemical background values. A few of the rock samples appeared altered and possibly mineralized; these were collected to determine the suite of elements associated with the observed alteration or mineralization.

All samples were analyzed semiquantitatively for 31 elements using direct-current arc emission spectrography (Grimes and Marranzino, 1968). Eight of the rock samples were analyzed for 43 elements using a similar method. Steam-sediment samples and four of the rock samples were also analyzed by inductively coupled argon plasma atomic-emission spectroscopy for antimony, arsenic, bismuth, cadmium, and zinc; the same samples were analyzed by atomic absorption for gold and mercury (Crock and others, 1987). Analytical data are from M.S. Erickson (written commun., 1987).

One rock sample collected from Devine Canyon Ash-flow Tuff (fig. 2) near the central part of the study area contains an anomalous concentration of silver (8.5 parts per million, or ppm). The rhyolite tuff is located in a gentle saddle, underlies an area of about 0.2 mi^2, and contains pumice fragments and small fractures filled with a gray-black mineral. Qualitative element identification of that mineral, using the scanning electron microscope, suggests that barite is present. However, no silver was detected in the mineral. The silver anomaly may reflect more mineralized rock at some unknown depth from which silver-enriched fluids have moved upward, possibly along small fractures. A stream-sediment sample collected 1.4 mi southwest and downstream from the rhyolite tuff exposure contains an anomalous concentration of silver (1.5 ppm). This anomalous value likely reflects the silver detected in the ash-flow tuff; no other silver anomalies were detected in stream-sediment samples.

A heavy-mineral concentrate sample collected downslope from an exposure of the Devine Canyon Ash-flow tuff in the Home Creek Wilderness Study Area, 8 mi north of the study area, also contains an anomalous concentration of silver (20 ppm) (Vander Meulen and others, 1988).

Geophysical Studies

Geophysical evaluation of the mineral resources of the Rincon Wilderness Study Area is based on interpretations of radiometric, aeromagnetic, and gravity surveys.

Radiometric data were compiled by Geodata International, Inc. (1980) for the National Uranium Resource Evaluation program of the Department of Energy. Coverage in the study area consists of four east-west flightlines, totaling 10 mi in length. The recorded flight altitudes generally ranged from 200 to 400 ft above the ground. Recordings were made of gamma-ray flux from radioactive isotopes of uranium, thorium, and potassium. Abrupt shifts in flux level were recorded over geologic contacts, but no anomalous concentrations of uranium or thorium were indicated in the study area.

A regional aeromagnetic survey was flown over the study area (U.S. Geological Survey, 1972). Flightlines were spaced at intervals of 2 mi and were flown at a constant barometric elevation of 9,000 ft above sea level. The northern part of the study area lacks magnetic anomalies. The easternmost part of a 6- by 12-mi, east-trending low covers the remaining parts of the study area. The large size and shape of the magnetic low and the lack of an anomaly in the northern part of the study area suggest that most of the rocks in the study area have low magnetization. Some of the rocks within the low also may be reversely magnetized because (1) the crest of a similar-shaped magnetic low overlies a topographic crest 2 mi north of the study area, and (2) the north end of a 13-mi-long band of magnetic lows that overlies a north-trending topographic ridge is 8 mi southeast of the center of the study area. Therefore, the basalt flows in the study area may be equivalent in age to the older, reversely magnetized part of the Steens Basalt (Mankinen and others, 1985). On the west side of the Catlow Rim, aeromagnetic contours along the south edge of the magnetic low are deflected slightly northward, further suggesting reversed magnetization of the surface rocks or shallowly buried rocks. Furthermore, the inferred greater thickness of reversely magnetized rocks along the axes of the magnetic lows in and to the north of the study area may be controlled by west- and northwest-trending horst and graben structures.

In 1986, the U.S. Geological Survey established 27 gravity stations in and adjacent to the study area. A preliminary gravity map prepared from these data shows that the study area is located in a broad, nose-shaped gravity high that extends westward from a major gravity high centered near the crest of the Pueblo Mountains (Plouff, 1987). Pre-Cenozoic basement rocks that underlie the gravity high in the Pueblo Mountains are denser than basement rocks at comparable depths. Gravity data coverage is too sparse west of Catlow Rim to show a gravity gradient across the rim that could be associated with basin-and-range block faulting.

Mineral Resource Potential

A rock sample collected from an exposure of Devine Canyon Ash-flow Tuff located near the center of the study area (fig. 2) contains an anomalous concentration of silver.

An anomalous concentration of silver is also detected in a stream-sediment sample collected 1.4 mi downstream from the tuff. The area underlain by the tuff has moderate potential for silver resources, level C certainty.

Lake shoreline bar deposits located adjacent to the northwest boundary of the study area have been utilized for sand and gravel aggregate. Similar shoreline deposits are located in the western part of the study area. Therefore, the northwestern part of the study area has high potential for sand and gravel resources, level D certainty.

The Rincon Wilderness Study Area is located 10 mi east of the Alvord Valley Known Geothermal Resource Area (KGRA) (Muffler, 1979; Cleary and others, 1981). Hot springs in this area and 32 mi north and 20 mi south of the study area are aligned along recently active basin-forming fault zones (Piper and others, 1939; Garside and Schilling, 1979). Although no hot springs are identified in the study area, geothermal waters may exist at depth along recent fault zones. The study area has low potential for geothermal resources, level B certainty.

Tertiary volcanic rocks underlying the Rincon Wilderness Study Area are not sources of hydrocarbons. Furthermore, geologic structures favorable for the production of oil and gas are not known to underlie the study area. Pre-Tertiary basement rocks exposed about 12 mi east of the study area are Mesozoic-age metamorphic and intrusive rocks (Walker and Repenning, 1965; Roback and others, 1987) and are unlikely sources or reservoirs for hydrocarbons. Sedimentary rocks that could serve as a source rock for oil and natural gas reserves are limited, and there is no geologic evidence to suggest that they are of greater extent at depth. The absence of rocks capable of producing or storing hydrocarbons suggests that the study area has no potential for oil and gas, level D certainty.

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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
	M/B MODERATE POTENTIAL	M/C MODERATE POTENTIAL	M/D MODERATE POTENTIAL
UNKNOWN POTENTIAL	L/B LOW POTENTIAL	L/C LOW POTENTIAL	L/D LOW POTENTIAL
			N/D NO POTENTIAL

LEVEL OF CERTAINTY →

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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.

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