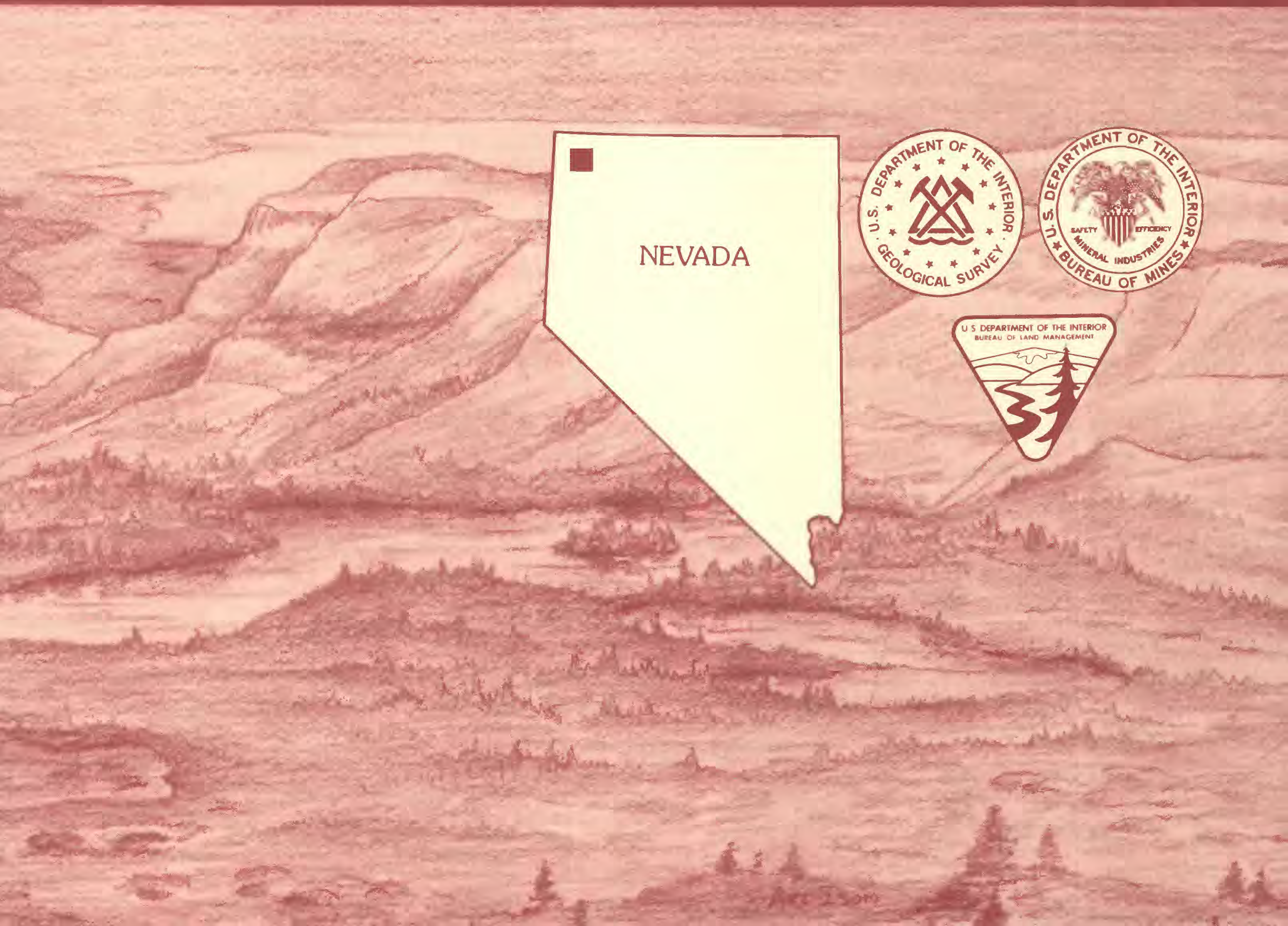
Mineral Resources of the Black Rock Desert Wilderness Study Area, Humboldt County, Nevada

U.S. GEOLOGICAL SURVEY BULLETIN 1726–E



Chapter E

Mineral Resources of the Black Rock Desert Wilderness Study Area, Humboldt County, Nevada

By J.P. CALZIA, W.A. LAWSON, J.C. DOHRENWEND, DONALD PLOUFF, and ROBERT TURNER
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U.S. GEOLOGICAL SURVEY BULLETIN 1726

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
HUMBOLDT AND PERSHING COUNTIES, NEVADA

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 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 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 Black Rock Desert Wilderness Study Area (NV-020-620), Humboldt County, Nevada.

CONTENTS

FIGURES

Mineral Resources of the Black Rock Desert Wilderness Study Area, Humboldt County, Nevada

By J.P. Calzia, W.A. Lawson, J.C. Dohrenwend, Donald Plouff, *and* Robert Turner
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SUMMARY

Abstract

The Black Rock Desert Wilderness Study Area (NV-020-620) covers 319,594 acres in western Humboldt County, Nev. The U.S. Bureau of Land Management requested mineral surveys on 174,300 acres of the wilderness study area. An appraisal of identified resources (known) and assessment of the mineral resource potential (undiscovered) of the smaller area, hereafter designated the study area, are described in this report. Geologic, geochemical, geophysical, and mineral surveys indicate that the study area has moderate potential for gold, silver, mercury, lithium, and geothermal resources and low potential for oil and gas resources although no mines or prospects were identified within this area.

Character and Setting

The Black Rock Desert Wilderness Study Area consists of a flat playa within the Black Rock Desert that is bounded by the Black Rock Range to the west and by the Jackson Mountains to the east. A group of north-trending hills, buttes, and mesas borders the study area to the northwest. Elevations on the playa range from 3,900 to 4,000 ft.

The Black Rock Desert is in the Basin and Range physiographic province. This province is characterized by northwest-trending fault-bounded mountains separated by wide parallel valleys. The Black Rock Desert is within a down-dropped fault block that is filled by Cenozoic sediments. Hills and mesas northwest of the study area are underlain by Triassic-Jurassic (see appendix for geologic time chart) phyllite, quartzite, and limestone, Cretaceous quartz monzonite, and Miocene-Pliocene tuffs, rhyolite flows, and basalt.

Mineral Resources

No mines are known or reported within the study area; the area has no identified resources. Rock and sinter samples collected near Pinto Hot Springs (fig. 1) contain low but anomalous concentrations of gold, silver, antimony, arsenic, barium, and mercury. This area has moderate resource potential for gold, silver and mercury in hot-spring deposits (fig. 2).

Lacustrine sediments have moderate resource potential for lithium. These sediments contain low lithium values and the geologic conditions are favorable for the concentration of lithium at depth.

All of the study area has moderate potential for geothermal resources. The Pinto Hot Springs Known Geothermal Resource Area (KGRA) and an unnamed hot spring are located near the north and south boundary of the study area, respectively. Nearly 27,000 acres are under lease near these geothermal areas.

The Black Rock Desert is classified prospectively valuable for oil and gas resources by the U.S. Bureau of Land Management (BLM). A recently completed oil and gas exploration well in the southeast corner of the study area was dry. The test well data suggest that the study area has low potential for oil and gas resources.

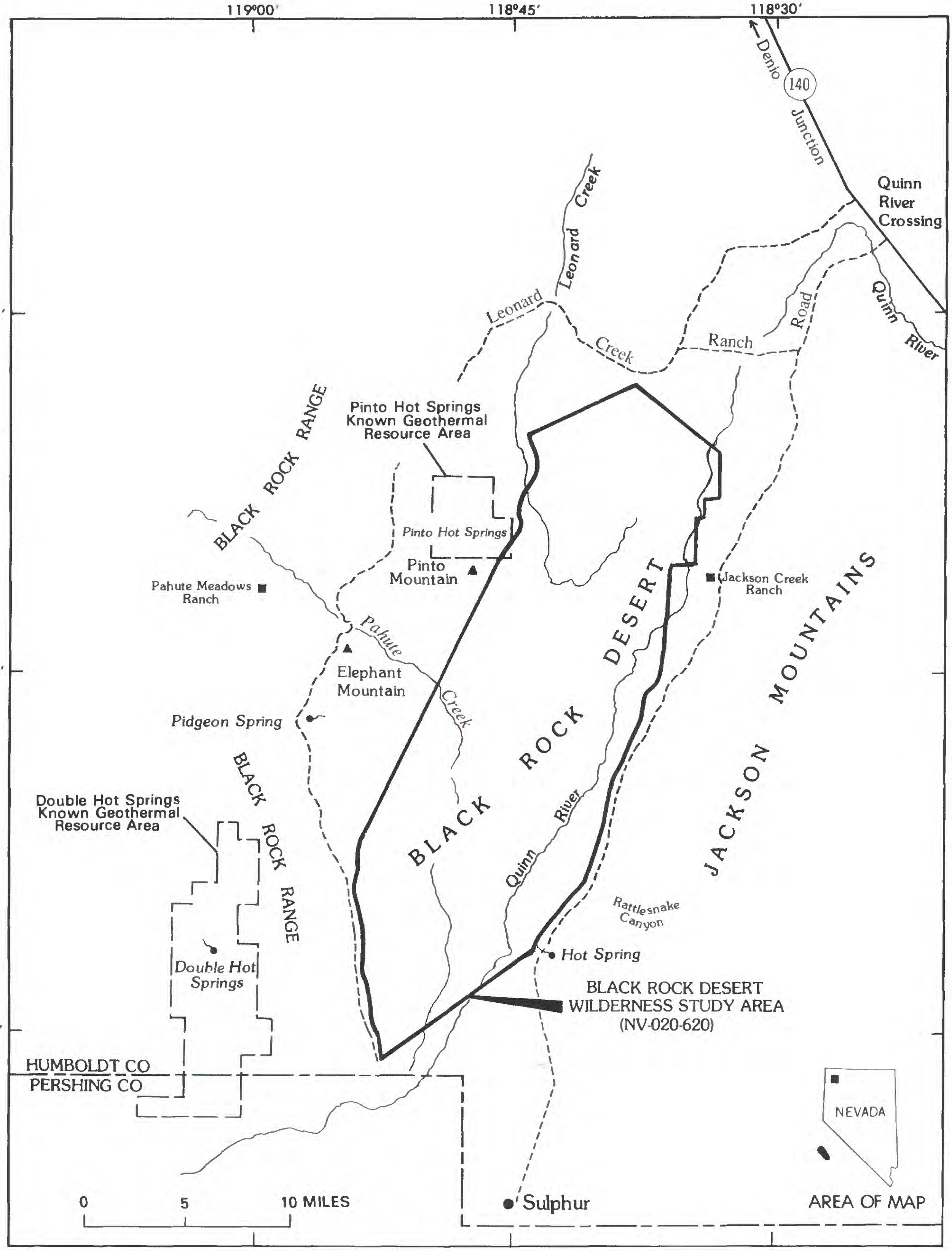

Figure 1. Index map showing location of the Black Rock Desert Wilderness Study Area, Humboldt County, Nevada.

INTRODUCTION

This mineral resource study is a joint effort by the U.S. Geological Survey and the U.S. Bureau of Mines. 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. The U.S. Bureau of Mines evaluates identified resources at individual mines and known mineralized areas by collecting data on current and past mining activities and through field examination of mines, prospects, claims, and mineralized areas. Identified resources are classified according to the system described by U.S. Bureau of Mines and U.S. Geological Survey (1980). Levels of mineral resource potential, certainty of assessment, and classification of identified resources are defined in the appendix.

Location and Physiography

The study area within the Black Rock Desert Wilderness Study Area (NV-020-620) covers 174,300 acres in western Humboldt County, Nev. The study area includes a large playa, located within the Black Rock Desert, bounded on the west and east by the Black Rock Range and the Jackson Mountains, respectively (fig. 1). Elevations on the playa range from 3,900 to 4,000 ft. The climate is arid. Vegetation, including saltbrush, grass, and greasewood, is very thick along the margin and in the northern third of the study area. The remainder of the playa is barren.

Access to the study area is permitted via Nevada Highway 140 between Winnemucca and Denio Junction, Nev. The Leonard Creek Ranch Road, a well-maintained dirt road, extends from Quinn River Crossing to Pahute Meadows Ranch (fig. 1). East-west vehicle traverses on the playa are possible only at the extreme southern end of the study area near Sulphur, and at the extreme north end along Leonard Creek Ranch Road. North-south traverses on either side of the Quinn River are possible with a four-wheel drive vehicle.

Previous Work

The geology and mineral resources of Humboldt County and northwest Nevada are described by Beatty (1955) and Willden (1964). Willden (1963), Sorensen (1986), and Sorensen and others (1987) described the geology and mineral resources of the Jackson Mountains. Lithium occurrences in Nevada are discussed by Vine and Dooley (1980). Barringer Resources, Inc. (1982), compiled reconnaissance geochemical and geostatistical data of the study area for the BLM.

Methods

The U.S. Geological Survey completed field investigations of the study area during the fall of 1985. The playa and the eastern margin of the Black Rock Range were mapped at 1:24,000 scale. Samples of the playa sediments and volcanic rocks along the west boundary of the study area were collected for geochemical and petrographic study. Water samples of hot springs adjacent to the study area were collected to determine mineral content and geothermal potential.

The U.S. Bureau of Mines (USBM) investigations included library research, a search of BLM and Humboldt County mining records for claim locations, and an examination of USBM production and Mineral Industries Location System records. Claim owners were contacted for additional information and to obtain permission to examine and publish data about their properties.

USBM field work in 1984 included examination of all known mineral properties within and immediately adjacent to the study area (Olson, 1985). Aerial and ground reconnaissance surveys were conducted to find new claims, prospects, or mineralized areas. All known and new sites were sampled and, if warranted, mapped. Detailed information is available from the U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Street, Spokane, WA 99202.

Acknowledgments

The U.S. Geological Survey and the U.S. Bureau of Mines thank Willis Bland for allowing us to establish base camps at Pahute Meadows Ranch and for his assistance in many logistical matters. Victor Dunn, BLM Winnemucca District, provided valuable information on the geologic and mineral character of the study area.

APPRAISAL OF IDENTIFIED RESOURCES

By J.E. Olson
U.S. Bureau of Mines

Mining History and Current Activity

Emigrants and prospectors enroute to the California gold fields began prospecting in Humboldt County around 1850. The Sulphur mining district, at the south end of the study area, evolved around 1870 when Indians first showed prospectors the location of native sulfur (Bailey and Phoenix, 1944). In 1908, rich silver veins were discovered at the south end of the district (Vanderburg, 1938). Production from the Sulphur mining district through 1920 totaled 15,369 tons of silver (Bailey and Phoenix, 1944). Mercury mining began about 1941 although cinnabar had been noted as early as 1882. Reported mercury production was 25 flasks through 1943. An old mining area near Sulphur was under development in 1984 as an open pit gold mine.

Current mineral interest in the study area consists of geothermal and oil and gas leases. Geothermal leases cover approximately 27,000 acres near Pinto Hot Springs and the unnamed hot spring near the southeast corner of the study area. Oil and gas leases cover most of the Black Rock Desert.

Mineral Deposits

No mines or prospects were identified within the study area. Twenty three small prospect pits and trenches are located in extremely fine-grained silicified rock north of Pinto Hot Springs. Seven

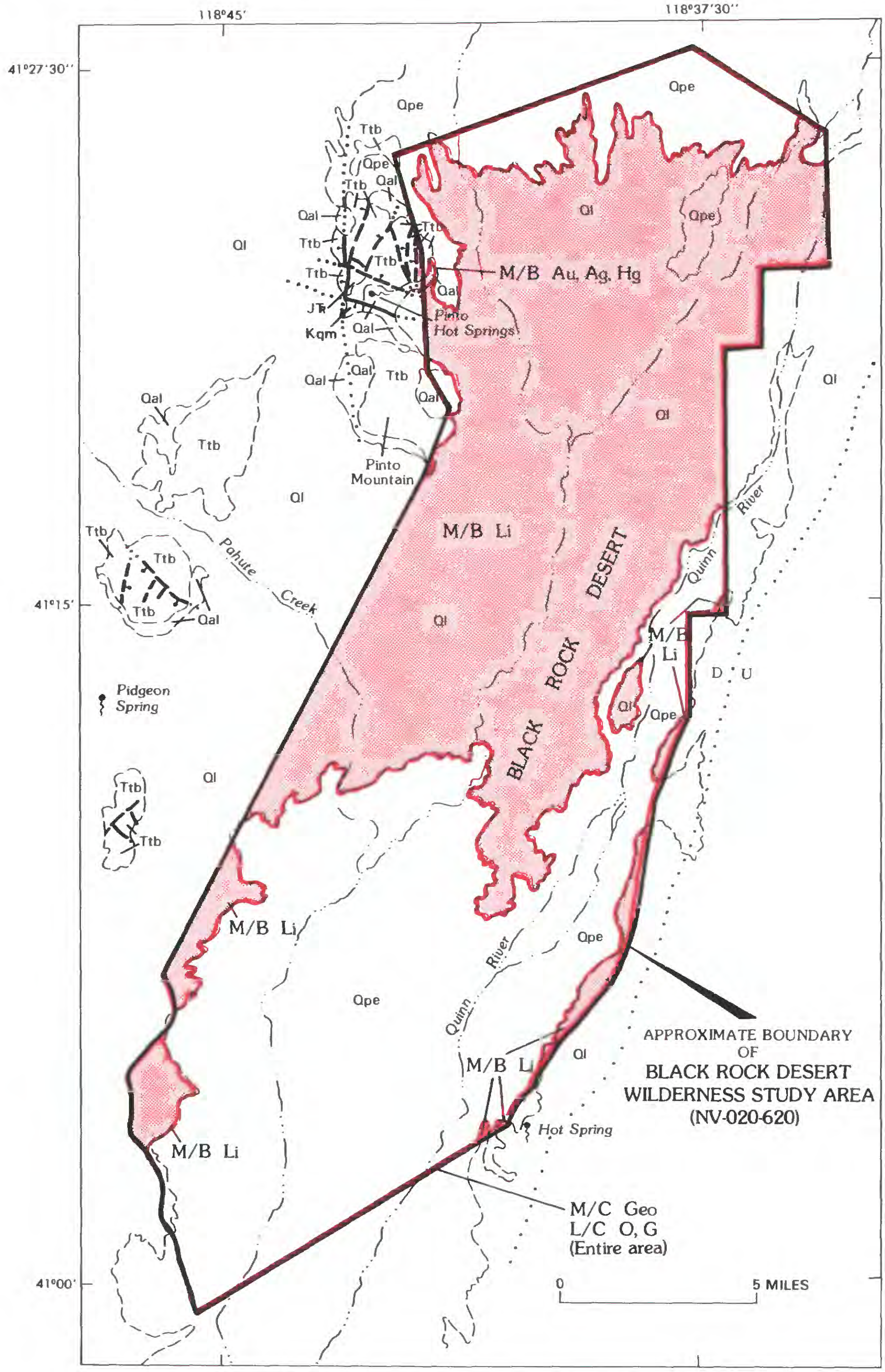

Figure 2. Mineral resource potential of the Black Rock Desert Wilderness Study Area, Humboldt County, Nevada.

representative samples from these pits contain 0.009 to 0.064 parts per million (ppm) gold. One sample from a pit located on a fault zone west of the hot springs contains 0.478 ppm gold and 120 ppm arsenic.

One small prospect pit was found near Pahute Creek just west of the study area. A sample of tuffaceous rocks near the pit contains 0.027 ppm gold and 1.87 ppm silver.

Samples of playa sediments near Leonard Creek at the north boundary of the study area contain anomalous concentrations of molybdenum and tungsten that are attributed to outwash from the Leonard Creek drainage basin. Samples of gravel from Leonard Creek contained a maximum 0.0002 troy ounce per cubic yard (oz/yd^3) gold.

The Pidgeon Spring area is underlain by Tertiary tuffs and younger playa deposits. One sample from a rhyolitic tuff contains 0.040 ppm gold and 59 ppm arsenic.

The playa deposits within the study area contain lithium and zeolite minerals. Lithium values range from 20 to 60 ppm. Davis (1976) suggests that lithium in surface clays may be anomalous at values exceeding 300 ppm. Zeolite minerals within the playa sediments are rare and are not of commercial interest.

EXPLANATION

Area with moderate mineral resource potential--Entire study area has moderate potential for geothermal resources

Area with low mineral resource potential--Entire study area has low potential for oil and gas resources

See appendix for definition of levels of resource potential and certainty of assessment

Commodities

Au	Gold
Ag	Silver
Hg	Mercury
Li	Lithium
Geo	Geothermal
O,G	Oil and gas

Geologic map units

Qal	Alluvium including hot-spring deposits (Holocene and Pleistocene)
Qpe	Playa and aeolian sand deposits (Holocene)
Ql	Lacustrine deposits of Lake Lahontan (Pleistocene)
Ttb	Tuffs and basalts (Oligocene and Miocene)
Kqm	Quartz monzonite (Cretaceous)
JTr	Quartzite, phyllite, and limestone (Jurassic or Triassic)

Contact--Dashed where approximately located

U D Normal fault--Dashed where approximately located; dotted where concealed; ball and bar on downthrown side; D on downthrown side; U on upthrown side

Figure 2. Continued.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By J.P. Calzia, W.A. Lawson, J.C. Dohrenwend, Donald Plouff, and Robert Turner
U.S. Geological Survey

Geology

The Black Rock Desert Wilderness Study Area is mostly underlain by Pleistocene and Holocene lacustrine sediments that unconformably overlie igneous and metamorphic rocks of Triassic to Tertiary age. The lacustrine sediments are overlain by and are intercalated with playa, eolian, fluvial, and younger alluvial fan deposits.

The oldest rocks in the Black Rock Range include Triassic or Jurassic quartzite, phyllite, and gray limestone (Stewart and Carlson, 1978). These rocks are intruded by a small Cretaceous quartz monzonite pluton and by aplite dikes. The aplite dikes cut the quartzite about 1 mi northwest of Pinto Hot Springs.

Late Oligocene and Miocene tuffaceous rocks and basalt flows unconformably overlie the pre-Tertiary rocks along the west side of the study area. The tuffaceous rocks consist of air-fall and waterlain massive to laminated tuffaceous sandstone, siltstone, diatomaceous shale, and pumiceous tuff breccia. Welded rhyolitic tuffs and vesicular basalt flows are interbedded with the tuffaceous deposits. The welded tuff is similar in composition and may be the Ashdown Tuff (D.C. Noble, oral commun., 1980). Sanidine from the Ashdown Tuff in the northern Black Rock Range yields potassium-argon ages of 23.7 to 25.3 million years (Ma) (Noble and others, 1970).

Basalt flows north of Pinto Hot Springs, characterized by abundant plagioclase phenocrysts and diktytaxitic textures, may correlate with the Steens Basalt. The Steens just north of the study area yields whole-rock potassium-argon ages of 15.4 and 16.6 Ma (Hart and Carlson, 1985).

Elephant Mountain west of the study area is a rhyolite plug flanked by rhyolite flows and tuffs. The rhyolite flows are locally flow banded and contain phenocrysts of quartz, sanidine, and biotite. The lower parts of the rhyolite flows are highly silicified. The tuffs are locally welded and contain perlite.

Tertiary rocks in the Black Rock Range are overlain by upper Pleistocene lacustrine sediments of Lake Lahontan. The Lake Lahontan shoreline that rings the Black Rock Desert forms a nearly continuous series of beach ridges, wave-cut notches, and cliffs at an approximate elevation of 4,370 ft. Littoral and nearshore sediments are characterized by multiple strandlines and beach ridges of well-sorted sand and gravel. These strandlines are especially prominent along the south and east margins of the Black Rock Desert. Locally, littoral sediments also form large spits. These relict features are particularly well developed near the highest shoreline and near the margins of the playa. Extensive lacustrine deposits in the north half of the study area form nearly flat-lying beds of predominantly fine sand, silt, and clay. All the lacustrine sediments have been pervasively dissected by a well-developed dendritic network of Holocene stream channels and are largely buried by eolian sand sheets and dunes.

Holocene playa sediments consist of clay, silt, and fine sand with minor evaporite salts. Interbedded lenses of fine sand and gravel are present near the playa margins. The playa sediments have little to no relief or dissection. They are intercalated with younger alluvial fans and fluvial sediments along the playa margins and are locally overlain by eolian deposits.

Eolian deposits consist of well-sorted, medium- to fine-grained sand. These deposits form extensive sand sheets and fields of coppice to barchanoid dunes. The sand sheets are generally less than 2 ft thick. The sand dunes range between 3 and 15 ft high; a few dunes exceed heights of 30 ft. The largest and highest dunes are mobilized beach ridges that are found along the south and east margins of the playa.

Fluvial sediments consist of moderately to poorly sorted silty sand and sandy to clayey silt reworked from the eolian and lacustrine deposits. The fluvial sediments include channel and flood-plain deposits along the Quinn River. Channels and flood plains generally range between 0.25 and 1.0 mi in aggregate width and are incised as much as 15 ft into the lacustrine sediments.

The alluvial fans consist of poorly sorted boulders, cobbles, and pebbles that reflect the composition of their source area. Younger alluvial fans form thin veneers, generally less than 15 ft thick, over the lacustrine and playa deposits.

Geochemistry

Geochemical studies within the study area consist of a reconnaissance survey by Barringer Resources, Inc. (1982), and a subsequent more detailed survey by the U.S. Geological Survey of anomalous areas that were defined by the reconnaissance survey. Barringer Resources, Inc. (1982), collected 269 samples within the study area. Approximately 90 percent of these samples are lacustrine sediments. Chemical data from these samples are difficult to evaluate because the lacustrine samples represent a composite of weathering products from several drainage basins that cover hundreds of square miles around the study area. There is no way to determine the source of any anomaly based on these sample data.

Detailed geochemical studies were made in the Pinto Mountain and the Elephant Mountain areas because these areas include the only large rock outcrops in or near the study area. Rock and nonmagnetic heavy-mineral concentrate samples from these areas were crushed and analyzed for 31 elements using techniques described by Grimes and Marranzino (1968). The rock samples were also analyzed for antimony, arsenic, bismuth, and zinc using techniques described by Crock and others (1983), and for gold and mercury using techniques described by Thompson and others (1968) and Koirtyohann and Khalil (1976), respectively.

Three sinter and two tuff samples were collected from the Pinto Mountain area. One tuff sample contained 0.1 ppm gold. Arsenic ranges from less than 5 ppm to 100 ppm, antimony ranges from less than 2 ppm to 6 ppm, and mercury ranges from less than 0.3 ppm to 1300 ppm. The sinter samples contained the highest values of arsenic, antimony, and mercury. Samples collected southwest of Elephant Mountain contain 42 ppm arsenic, as much as 300 ppm lead, and 120 ppm zinc.

Geophysics

Geophysical studies in the study area consist of gravity and aeromagnetic surveys. Four gravity stations were established by Peterson and Hassemer (1977) as part of the geothermal resource study of the Pinto Hot Springs KGRA. Data at two additional stations were acquired from the National Geophysical Data Center (1984). These data were supplemented by stations established along roads east and west of the study area by Donald Plouff, C.F. Erdmann, and V.E. Langenheim (unpublished data, 1984).

The study area is dominated by a broad gravity low with an east-west width of about 11 mi. The amplitude of the gravity low is roughly 30 milligals. The gravity data suggest that the lacustrine sediments are more than 5,000 ft thick, assuming a density contrast of 0.5 grams per cubic centimeter between the sediments and bedrock.

An aeromagnetic survey of the region was flown at a constant barometric elevation of 9,000 ft above sea level with east-west flightlines spaced at 2 mi intervals. The aeromagnetic intensity pattern over most of the study area is featureless because of low magnetization of the lacustrine sediments. The aeromagnetic data suggest that the lacustrine sediments are thickest about 1 mi west of the Quinn River.

Mineral Resource Potential

Geologic and geochemical data suggest that there is potential for several types of resources within the study area, even though no mines are present. These resources include gold, silver, and mercury associated with hot springs, lithium in lacustrine sediments, geothermal, and oil and gas. Each of these types of deposits are assigned moderate or low resource potential at various certainty levels as defined in the appendix.

The Pinto Hot Springs area has moderate potential for gold, silver, and mercury resources in hot-spring deposits at certainty level B. Berger (1986) reported that hot-spring gold-silver deposits often occur along fractures in brecciated rhyolitic tuffs and flows. Hot-spring mercury deposits occur in similar geologic environments and are often associated with hot-spring gold-silver deposits. Anomalous concentrations of arsenic and antimony in sinter are typically associated with those gold-silver and mercury deposits.

Lacustrine sediments within the study area have moderate potential for lithium resources at certainty level B. Lithium concentrations in near-surface samples ranges from 20 to 60 ppm. Bohannon and Meier (1976) reported that near-surface lithium values may not be reliable indicators of resources of depth because most large lithium deposits form at depth in deep sedimentary basins. Vine (1975) concluded that desert playas are good targets for lithium exploration because (1) structural basins created by block faulting restrict the escape of soluble clay-size constituents; (2) deep-seated faults may act as conduits for circulating groundwater; (3) high temperature gradients, especially near hot springs, may drive groundwater convection cells; and (4) excess evaporation relative to precipitation provides for lithium detection in the near-surface environment.

All of the study area has moderate resource potential for geothermal resources at certainty level C. Surface spring temperatures range from 150 to 172 ^{O}F at Pinto Hot Springs and from 152 to 170 ^{O}F at the unnamed hot spring in the southeast corner of the study area. The BLM may declassify the Pinto Hot Springs KGRA because no bids were received for this area during geothermal lease sales held in 1984 and 1985. This KGRA was established in 1975 on the basis of competitive interest and on geologic evidence.

The entire study area has low potential for oil and gas resources at certainty level C. Willden (1979) reported that the Black Rock Desert was highly favorable for oil and gas exploration because organic-rich source rocks crop out in the Jackson Mountains and probably occur at depth in the Black Rock Desert. The BLM classified the study area as prospectively valuable of oil and gas resources. An exploratory well, located in the southeast corner of the study area, was completed in 1983 to a total depth of 7,931 ft and is dry. The test-well data suggest that the oil and gas potential of the Black Rock Desert is low.

The playa and lacustrine sediments have no potential for either sodium and potassium or sand and gravel resources. Although the Black Rock Desert is classified prospectively valuable for sodium and potassium resources by the BLM, little to no evaporite salts or alkali elements were noted in rock, stream sediment, and groundwater samples. The lack of evaporite salts and brines precludes the potential for sodium and potassium resources. Well-sorted sand and gravel deposits are thin and limited to ancient beach ridges. Larger more accessible deposits are located east of the study area closer to metropolitan areas.

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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

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

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

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

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

Levels of Certainty

<table>
<tr><td rowspan="4">U/A
UNKNOWN POTENTIAL</td><td>H/B
HIGH POTENTIAL</td><td>H/C
HIGH POTENTIAL</td><td>H/D
HIGH POTENTIAL</td></tr>
<tr><td>M/B
MODERATE POTENTIAL</td><td>M/C
MODERATE POTENTIAL</td><td>M/D
MODERATE POTENTIAL</td></tr>
<tr><td rowspan="2">L/B
LOW POTENTIAL</td><td rowspan="2">L/C
LOW POTENTIAL</td><td>L/D
LOW POTENTIAL</td></tr>
<tr><td>N/D
NO POTENTIAL</td></tr>
<tr><td>A</td><td>B</td><td>C</td><td>D</td></tr>
</table>

LEVEL OF RESOURCE POTENTIAL →

LEVEL OF CERTAINTY →

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

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

GEOLOGIC TIME CHART

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

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

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

[2]Informal time term without specific rank.

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DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

CONTENTS

[Letters designate the separately published chapters]

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