Mineral Resources of the Riordans Well Wilderness Study Area, Nye County, Nevada

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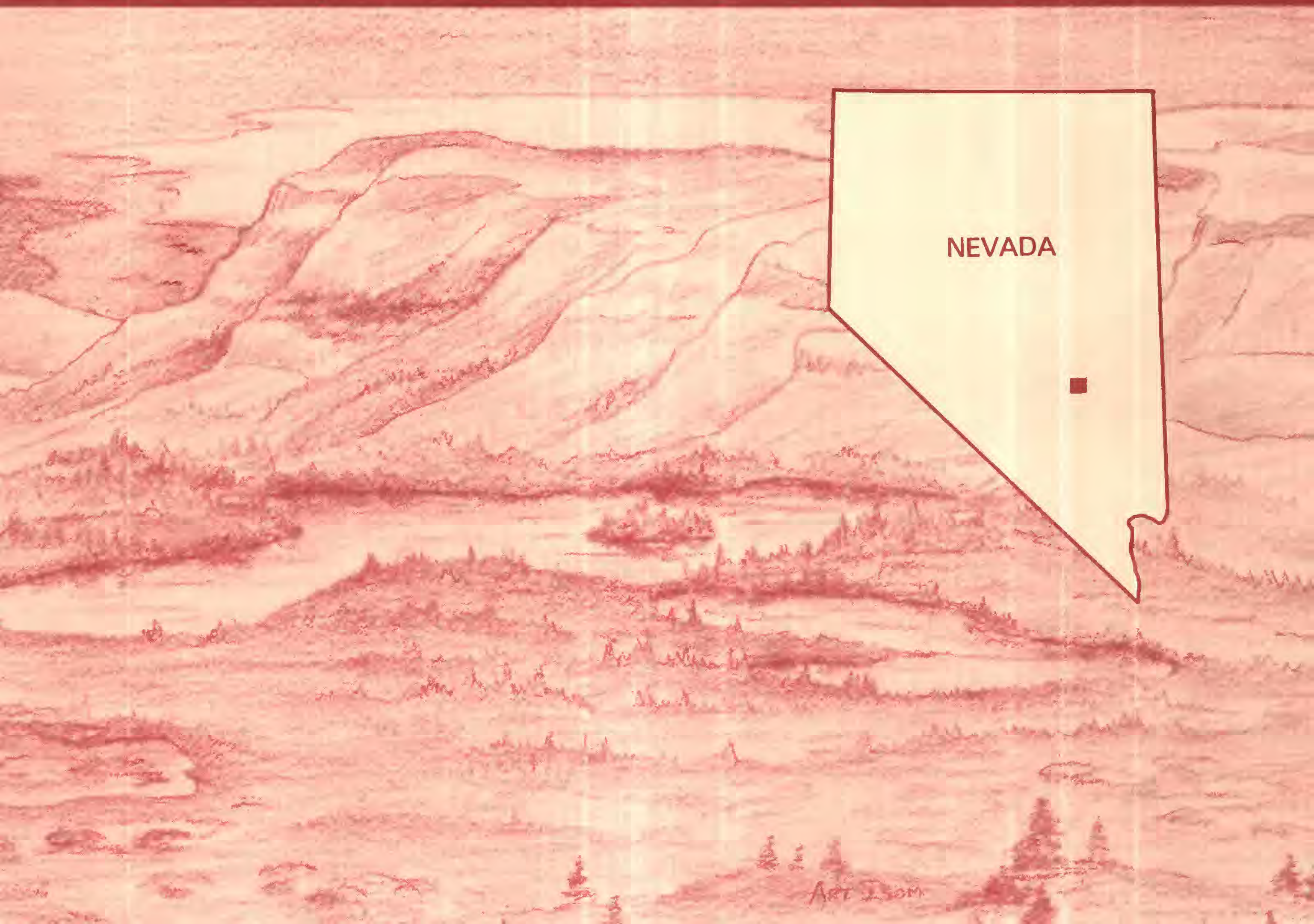

Chapter H

Mineral Resources of the Riordans Well Wilderness Study Area, Nye County, Nevada

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U.S. GEOLOGICAL SURVEY BULLETIN 1731

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—CENTRAL NEVADA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U. S. GEOLOGICAL SURVEY
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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys 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 Riordans Well Wilderness Study Area (NV-040–166), Nye County, Nevada.

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PLATE

[Plate is in pocket]

FIGURES

Mineral Resources of the Riordans Well Wilderness Study Area, Nye County, Nevada

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SUMMARY

Abstract

The Riordans Well Wilderness Study Area (NV-040-166) lies in the Basin and Range physiographic province of east-central Nevada (fig. 1). The U.S. Bureau of Land Management (BLM) requested that a mineral survey of 37,542 acres of the wilderness study area in Nye County, Nev., be conducted by the U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (USBM) during 1983, 1985, and 1986. New geologic mapping of the area was completed, geochemical sampling of the area was conducted, geophysical characteristics were evaluated, and unpatented claim blocks in the area were investigated. There are no identified (known) mineral resources in the study area. Several types of undiscovered mineral resources may be present in the area. The mineral resource potential for each type is given below.

The Riordans Well Wilderness Study Area has high energy resource potential for petroleum (fig. 2), although specific traps have not been identified. Almost half of the area has been leased for oil and gas (fig. 3).

Moderate mineral resource potential is designated for three types of metal occurrence in two parts of the study area (fig. 2). The western part of the study area has moderate potential for tungsten and polymetallic base-metal (copper, lead, zinc, molybdenum, and bismuth) deposits in hydrothermal (low- to medium-temperature) replacement deposits in low-grade metamorphic rocks and for gold and silver in quartz veins associated with the replacement mineralization. The southeastern and eastern parts of the study area have moderate potential for gold in disseminated deposits associated with jasperoid occurrences.

The remainder of the area has low resource potential for other metals, nonmetals (magnesite, high-purity limestone or dolostone), or other energy resources (geothermal energy, uranium, and coal).

Character and Setting

The Riordans Well Wilderness Study Area is in the northern Grant Range 18 mi southeast of Currant, northeastern Nye County, Nev. (fig. 1). Improved and unimproved roads provide access to the eastern and western sides of the wilderness study area. Old unimproved roads along the northern, northwestern, and southwestern boundaries of the wilderness study area are generally impassable.

The eastern side of the Grant Range is topographically gentle and generally heavily forested; the western side is cliffy and deeply dissected. The total relief is more than 4,500 ft (feet) between Railroad Valley, west of the wilderness study area, and the highest point on an unnamed peak in the southern part of the area (9,352 ft).

The Grant Range is an east-tilted fault block. The faulting exposed a stratigraphic section, from west to east, of thick carbonate sedimentary rocks of the Paleozoic (see geologic time scale in Appendix) continental shelf that are overlain by Tertiary basin deposits and by a sequence of Tertiary volcanic and basin-fill deposits. The oldest exposed Paleozoic rocks are metamorphosed. Rocks of the Grant Range show a complex structural history developed during Mesozoic compressional and Tertiary extensional events.

The wilderness study area is north of the Troy and Willow Creek mining districts (fig. 1) and contains three groups of unpatented lode claims (fig. 3).

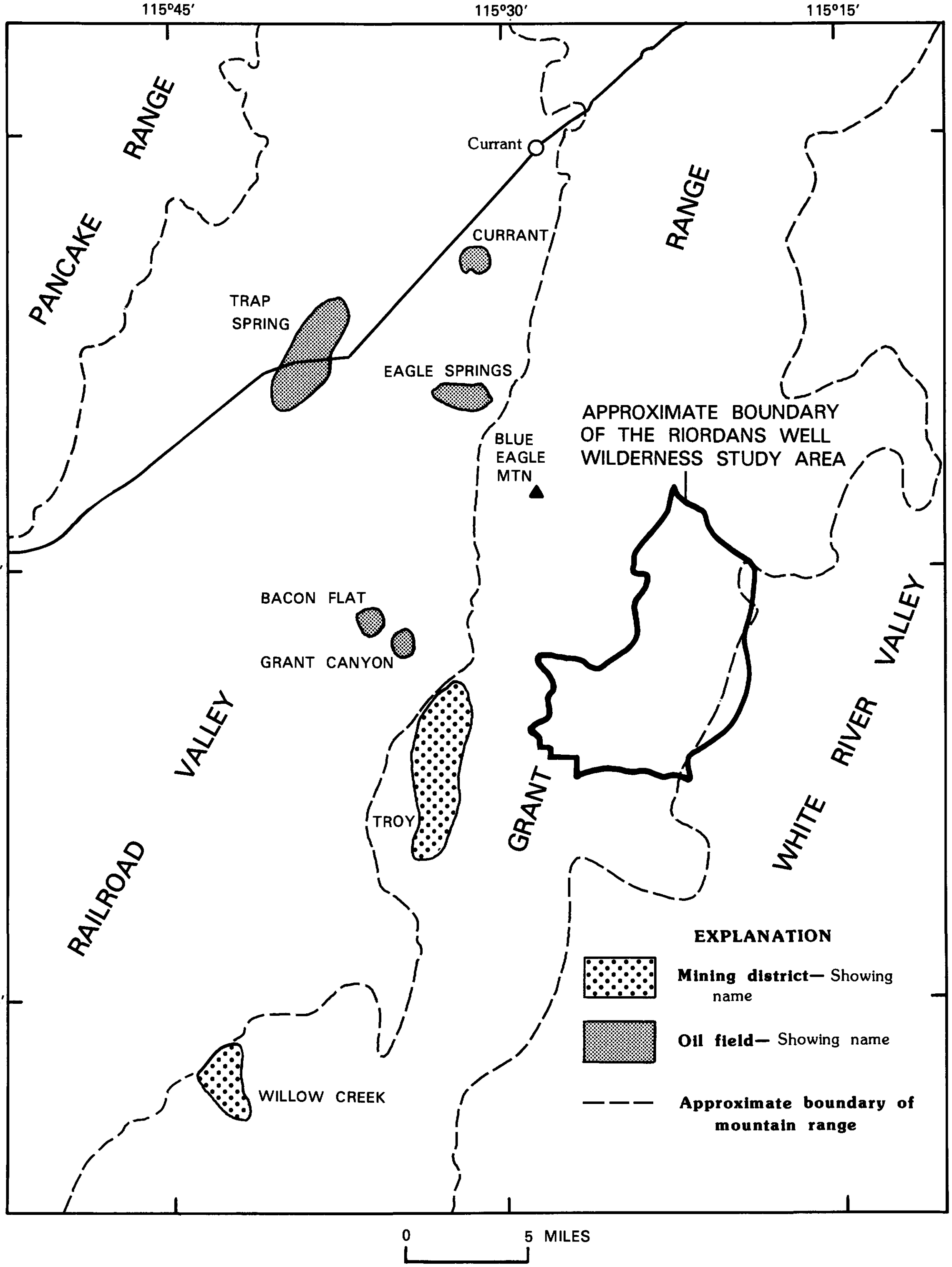

Figure 1. Index map showing location of the Riordans Well Wilderness Study Area, Nye County, Nevada, and nearby mining districts and oil fields.

Mineral Resource Potential

The entire wilderness study area has a high energy resource potential for petroleum (Sandberg, 1983). Wells in oil fields in Railroad Valley on the west side of the wilderness study area (fig. 1) have been active since 1954 (Bortz and Murray, 1979), and commercial exploration and production are ongoing. Both Paleozoic and Tertiary source rocks (Poole and Claypool, 1984) are present in the wilderness study area.

These source rocks are at optimum maturation for oil and gas generation (Sandberg, 1983). Many structures are present for fluid migration and trapping in reservoirs; however, effective reservoir seals and traps may be absent in the wilderness study area.

Two areas in the western part of the wilderness study area have moderate mineral resource potential for tungsten in hydrothermal replacement deposits (fig. 2). These areas are south of the Galena claim block, which has a history of prospecting and limited tungsten production (Lund and others, 1987). Polymetallic base-metal (copper, lead, zinc, molybdenum, and bismuth) anomalies in stream-sediment samples helped to define areas of mineral resource potential for tungsten. These two areas are geologically and geochemically similar to the Troy mining district that lies 4 mi (miles) south and west (fig. 1).

Anomalous concentrations of base metals were found in samples from the Riordans Well Wilderness Study Area. The western part of the wilderness study area has moderate mineral resource potential for copper, lead, zinc, molybdenum, and bismuth in hydrothermal replacement deposits (fig. 2) in metamorphic rocks.

A moderate mineral resource potential for gold and (or) silver exists in different settings in two parts of the wilderness study area. In the western corners of the wilderness study area (fig. 2), there is a moderate potential for gold and silver in quartz veins associated with replacement deposits; these veins are in steep fault zones in low-grade metamorphosed lower Paleozoic dolomitic schists and marbles. Geochemical anomalies defined by stream-sediment-concentrate samples provide additional evidence of this potential. Two areas in the southeastern and eastern parts of the wilderness study area have a moderate potential for gold in disseminated deposits (fig. 2) associated with jasperoid occurrences. Many jasperoid breccias in this area are along high- and low-angle normal faults that cut upper Paleozoic shale and limestone units.

The remainder of the area has low resource potential for other metals, nonmetals (magnesite, high-purity limestone or dolostone), or other energy resources (geothermal energy, uranium, and coal).

INTRODUCTION

At the request of the BLM, 37,542 acres of the Riordans Well (NV–040–166) Wilderness Study Area in northeastern Nye County, Nev., were studied. In this report, the studied area is called the "wilderness study area" or just the "study area." The wilderness study area is in east-central Nevada 18 mi southeast of Currant, Nev. (fig. 1), and 65 mi southwest of Ely, Nev. Several improved and unimproved roads provide access to the eastern and western sides of the wilderness study area (pl. 1). Because old unimproved roads along the northern, northwestern, and southwestern sides of the study area have been eroded, access from these sides is difficult. The wilderness study area includes much of the eastern side of the northern Grant Range, which is an east-tilted fault block. The western side of the range is cliffy and has been dissected by many deep canyons; the eastern side of the range is more gentle. The wilderness study area is, in general, heavily forested by pinon pine and juniper trees.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of 37,542 acres of the wilderness study area and is the product of several separate studies by the USBM and the USGS. Identified resources are classified according to the system of the U.S. Bureau of Mines and the U.S. Geological Survey (1980), which is shown in the Appendix of this report. Identified resources are studied by the USBM. Mineral resource potential is the likelihood of occurrence of undiscovered metals and nonmetals, of industrial rocks and minerals, and of undiscovered energy sources (coal, oil, gas, oil shale, and geothermal sources). It is classified according to the system of Goudarzi (1984) and is shown in the Appendix. Undiscovered resources are studied by the USGS.

Investigations by the U.S. Bureau of Mines

The USBM researched all available information from literature, county mining records, and USBM, Nevada Bureau of Mines, and BLM files. Claimants, mine owners, and mining companies were contacted to obtain information on claim location, history, and economic geology. Field studies involved searches for all mines, prospects, and claims indicated by prefield studies to be in the study area. In addition, ground and air reconnaissance was performed to find areas of mineralization.

Field work was conducted during the summer of 1985. During the study, 349 samples were collected. The samples were crushed, pulverized, and split; one split was sent to the USBM Research Center, Reno, Nev. Gold and silver were analyzed for by fire-assay inductively coupled plasma (ICP) methods. Other elements were analyzed for using ICP and atomic-absorption methods. At least one sample from each mineralized structure was analyzed for 40 elements by semiquantitative spectrometry. Sample analyses are on file at the U.S. Bureau of Mines Western Field Operations Center, E. 360 Third Ave., Spokane, WA 99202, and are available to the public. Hamilton (1987) reported results of the USBM studies.

Investigations by the U.S. Geological Survey

In June 1983, USGS geochemists collected 119 samples of stream sediment, 114 samples of heavy-mineral concentrate, and 18 samples of spring water at

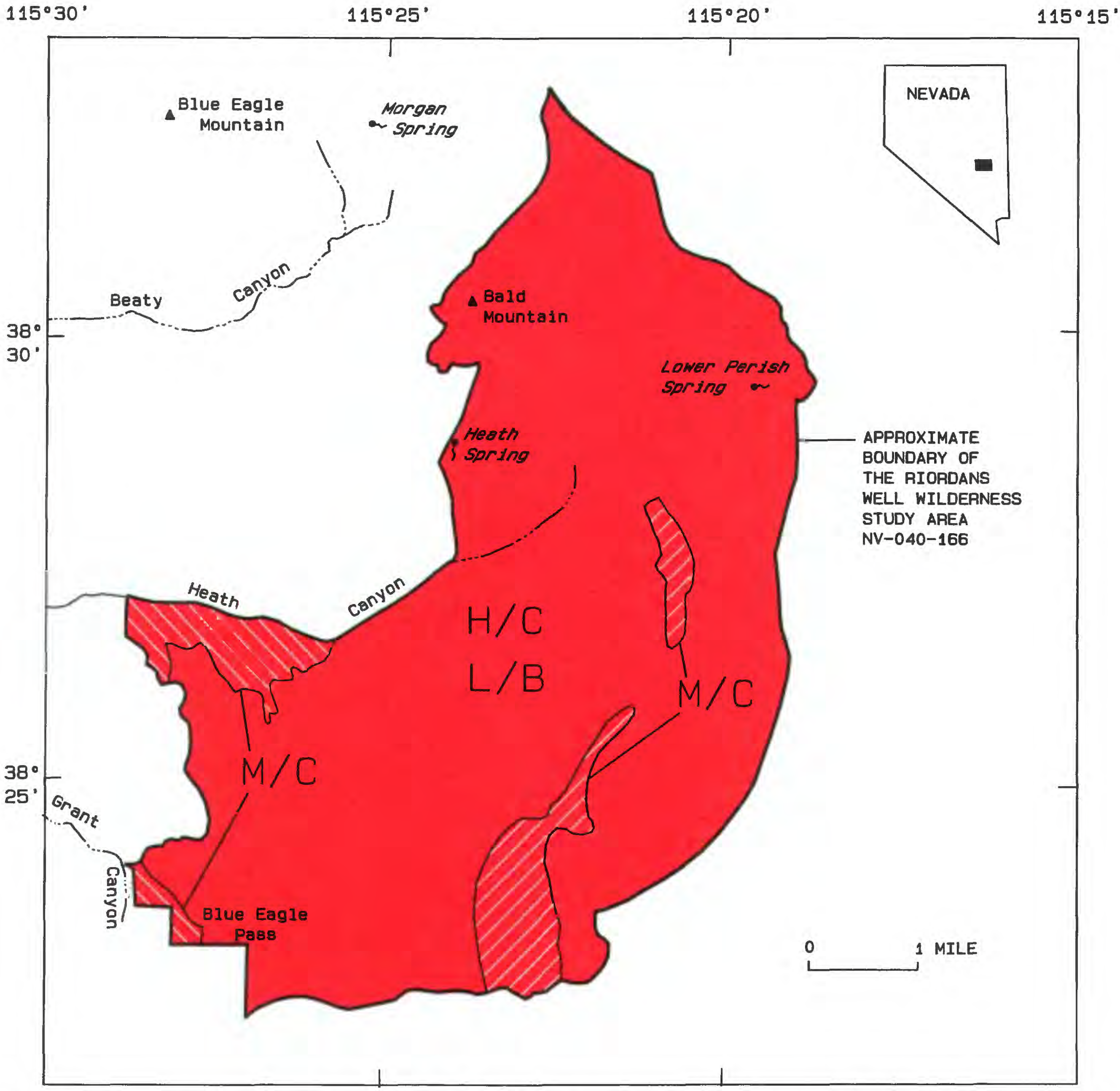

Figure 2 (above and facing page). Summary map showing mineral resource potential of the Riordans Well Wilderness Study Area, Nevada.

sites in and near the wilderness study area. Rock samples were collected at eight sites that had visible signs of alteration, veining, or possible sulfide minerals. The sampling and analytical procedures (see the section on "Geochemistry") are described, and detailed analytical results are presented in a report by Hofstra and others (1984).

New gravity measurements were made in the study area during the fall of 1985 by USGS geophysicists. Aeromagnetic studies included both a newly flown survey (U.S. Geological Survey, 1985) and older data (U.S. Geological Survey, 1976, 1979).

During the summer of 1986, USGS geologists mapped the wilderness study area and additional areas (Karen Lund and L.S. Beard, unpub. mapping) between the study area and Railroad Valley and the Blue Eagle Wilderness Study Area to the west (Lund and others, 1987).

EXPLANATION

H/C Geologic terrane having high energy resource potential for petroleum, at certainty level C—Applies to entire study area

Geologic terrane having high energy resource potential for petroleum at certainty level C and moderate mineral resource potential for commodities as indicated below, at certainty level C

M/C Gold

M/C Gold and silver; tungsten; copper, lead, zinc, molybdenum, and bismuth

L/B Geologic terrane having low resource potential for other metals, nonmetals, coal, and geothermal energy, with certainty level B—Applies to entire wilderness study area

Levels of certainty

B Available information suggests level of resource potential

C Available information gives good indication of level of resource potential

Acknowledgments

The BLM personnel of the Ely District office provided much help; we are especially indebted to William Robison, geologist. The assistance and cooperation of claim owners Icarus Exploration, Permian Exploration, and Lacana Gold, Inc., are very much appreciated. USBM geologist Fredrick Johnson is commended for his valuable contributions to the study.

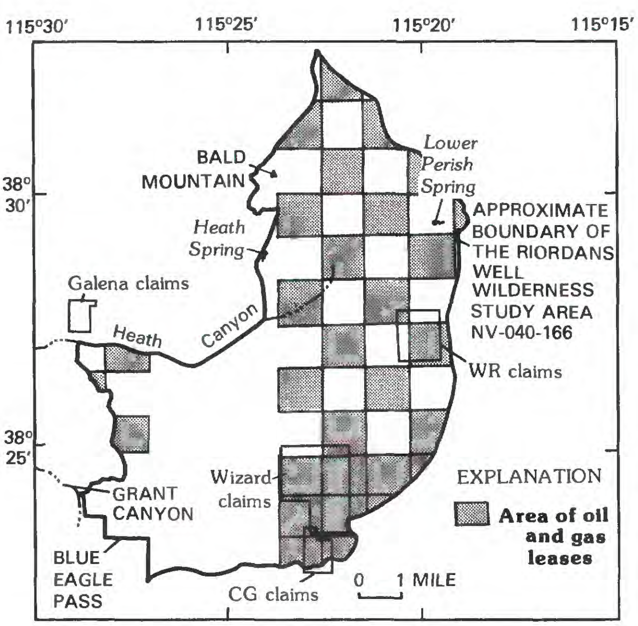

Figure 3. Map showing mining claims and oil and gas leases in and near the Riordans Well Wilderness Study Area, Nevada.

APPRAISAL OF IDENTIFIED RESOURCES

By Michael M. Hamilton
U.S. Bureau of Mines

Mining and Exploration History

The earliest mining activity was in 1868 when ore deposits were discovered about 5 mi southwest of the wilderness study area in Troy Canyon (Raymond, 1874, p. 227). The Troy unorganized mining district (fig. 1) was centered on the Troy mine, the site of the original ore discovery. In 1905 another small mining district was started in Irwin Canyon, 4 mi west of the wilderness study area (Hill, 1916, p. 141). Between 1873 and 1963, a total of $31,781 in gold, silver, and some lead was produced from quartz veins in sedimentary rock near the Troy pluton (Kleinhampl and Ziony, 1984).

In the 1950's, tungsten was mined at the Terrell and Nye mines about 4 mi southwest of the wilderness study area. Production was from tactite bordering the Troy pluton and totaled between $100,000 and $250,000 (Kleinhampl and Ziony, 1984).

Prospecting in the wilderness study area probably coincided with activity in the Troy mining district. Claims were first located in the 1920's at the southern side of the wilderness study area. During this time, the south-central part of the wilderness study area was explored, and many small prospect pits, trenches, and one shaft were dug. The three properties active in 1986, the CG, Wizard, and WR, total 141 lode claims and were located between 1980 and 1984 as part of regional exploration programs for Carlin-type gold deposits in eastern Nevada. Other than geochemical surveying, there has been no mining activity on these properties as of 1986.

The Eagle Springs oil field in Railroad Valley was discovered in 1954 and was still producing in 1986. Exploration for oil in the White River Valley on the eastern side of the wilderness study area has been sporadic throughout the 1960's, 1970's and 1980's. Currently (1986), almost one-half of the wilderness study area is covered by oil and gas leases (fig. 3).

Prospects and Mineralized Sites

Areas of jasperoid deposits, altered bedrock, and concentrations of pathfinder elements are at the WR claims on the eastern side of the wilderness study area and the CG and Wizard claims on the south-central side (fig. 2). Anomalously high amounts of pathfinder elements, such as arsenic, antimony, and mercury, along with siliceous deposits of jasperoid and acid-leach bedrock, are, in this region, good indicators of low-grade gold and silver mineralization. These claims and adjacent areas are discussed below.

In addition, several exposures of jasperoid and altered bedrock along faults in the Mississippian Joana Limestone and Chainman Shale occur near the head of Heath Canyon near Heath Spring. Of the thirteen rock samples collected in this area, one contained as much as 1.213 ppm (parts per million) silver, 80 ppm arsenic, and 4 ppm antimony. These occurrences are small and lack economic concentrations of significant elements, and no resource was identified. Another area of jasperoid and altered bedrock is along the contact of the Pennsylvanian and Mississippian Ely Limestone and Mississippian Chainman Shale about 0.5 mi northeast of the northeast corner of the Wizard claims. Of the twenty samples collected, one contained as much as 0.695 ppm gold, 2.360 ppm silver, 8,700 ppm arsenic, and 10.9 ppm antimony. These concentrations suggest similar mineral occurrences as were found on the Wizard claims, but no resource was identified.

CG Prospect

CG claims nos. 1–18 were located in 1980 by Permian Exploration, Salt Lake City, Utah. During that year, a soil-sample survey was performed. An additional seven claims were located in 1982. In 1986 the prospect was still held by Permian Exploration.

Exploration in the prospect area was most likely for low-grade, bulk-tonnage gold and silver deposits along a fault in the Joana Limestone. The jasperoid and heavily iron stained, altered rocks exposed on the southwestern side of the prospect were probably the initial discovery. Two old prospect pits are in this area. Subsequent soil sampling outlined geochemical anomalies in the Joana Limestone near the fault.

A total of 47 grab and chip samples were collected on the property. Five samples contained gold averaging 0.05 ppm, 26 contained silver averaging 0.6 ppm, 15 contained arsenic ranging from 50 ppm to 1,830 ppm, and 5 contained antimony ranging from 5 ppm to 99 ppm. The geochemical soil survey by Permian Exploration found mercury contents as high as 1,800 parts per billion (ppb) and arsenic anomalies as high as 520 ppm.

Wizard Prospect

The Wizard claims nos. 1–76 were located in 1984 by Thomas Frank of Reno, Nev. On the northwestern side of the property is a 40-ft-deep shaft and eight prospect pits. Located in 1926 as the Iron Cap claims, these workings were hand dug. In 1986, the claim owner was Icarus Exploration, Portland, Ore.

Bedrock here consists of limestone, conglomerate, sandstone, and shale of the Ely Limestone, Chainman Shale, and Joana Limestone. Tertiary volcanic rocks occur on the southeastern side of the prospect. Jasperoid, altered rocks, and gossan occur along faults and bedding planes. Limestone units contain some marble and travertine and small amounts of chlorite and epidote. Sandstone has liesegang banding in places. Several jasperoid exposures contain features typical of disseminated gold and silver deposits, such as vertical siliceous breccia zones and silica-cap deposits along bedding. The largest area of altered and silicified rocks is on the northwestern side of the prospect. The alteration is probably associated with faults in the Joana Limestone.

A total of 188 rock-chip, grab, and select samples were collected from exposures of jasperoid and altered country rock. Fifty-six samples contained gold averaging 0.05 ppm and ranging from 0.018 ppm to 0.547 ppm; 35 samples contained silver averaging 1.364 ppm and ranging from 0.340 to 12.33 ppm; 50 samples contained arsenic ranging from 52 ppm to 1,760 ppm; and 11 samples contained antimony ranging from 5.0 ppm to 38 ppm. In addition, 10 samples, mainly from the western side of the property, had mercury (≤ 2 ppm).

WR Prospect

The WR group of 40 claims was located in 1982 by Inspiration Development Co., Claypool, Ariz., as a disseminated gold prospect. While staking claims, a soil geochemical sampling program was performed using 100-ft sample intervals on a 500-ft grid. Lacana Mining Corp., in 1983, evaluated the property for gold (Lacana Mining Corp., written commun., 1986). Interest in the property waned after 1983, and the property was still held by Inspiration Development in 1986.

Interest has focused on areas of jasperoid along bedding planes at the contact between the Mississippian Joana Limestone and Chainman Shale. Volcanic rocks on the eastern side of the property consist of rhyolite ash-flow tuffs.

Eighty-one grab and chip samples were collected: 68 from the claim group and 13 from exposures of jasperoid north and south of the claim group. Twelve samples of sedimentary rock contained gold averaging 0.045 ppm, 22 samples contained silver averaging 0.708 ppm, 10 samples contained arsenic ranging from 63 to 330 ppm, and 7 samples contained antimony ranging from 6.0 to 17.1 ppm. Seven samples of volcanic rock contained gold averaging 0.025 ppm.

Conclusions

There are no identified resources in the study area; however, the CG, Wizard, and WR prospects are logical exploration targets for gold deposits. The prospects have geological and geochemical characteristics similar to gold deposits in eastern Nevada such as at the Rain and Alligator Ridge mines. The presence of jasperoid or siliceous caps indicate that most of the hydrothermal systems and possible gold-bearing zones, if present, are at depth. The Wizard and CG prospects had the highest concentrations of pathfinder elements and the largest areas of low-grade gold.

The current value for gold ($391 per ounce, Engineering and Mining Journal, January 1987) combined with new, inexpensive methods of heap leaching to recover gold and silver has created considerable interest in low-grade, bulk-tonnage deposits. Most of the new domestic gold mines are on deposits of this type, many of which are in Nevada.

Extensive areas of limestone and sand and gravel occur within the wilderness study area. However, the great distance to any potential market and high transportation cost combined with the abundance of these commodities in the region prevent these materials from being classified as identified resources.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Karen Lund, L.S. Beard, H.R. Blank, Jr., and A.H. Hofstra
U.S. Geological Survey

Geology

The Riordans Well Wilderness Study Area, in east-central Nevada, is in the middle of the Basin-and-Range province. During the Paleozoic, this region was on the continental shelf of North America and was the site of deposition of about 20,000 ft of predominantly carbonate rocks. This part of Nevada lies east of the regions most affected by deformation that occurred during the Devonian to Mississippian (Antler) and Permian to Triassic (Sonoma) orogenies and west of the main zone of thrust-fault ramping that occurred in Utah during late Mesozoic to early Tertiary (Sevier) orogenic activity. Lower Tertiary sedimentary deposits in and near the wilderness study area accumulated in basins that may have been caused by upper crustal disturbances during the late Mesozoic to early Tertiary thrust faulting. The present-day Basin-and-Range physiography formed during later Tertiary crustal extension that was concomitant with volcanism and local sedimentation. The regional extension is expressed by both low- and high-angle normal faults, the youngest of which brought about the relative uplift and tilting of the mountain ranges.

Stratigraphy

The stratigraphic succession in the wilderness study area is divisible into generalized Paleozoic and Tertiary sequences that were deposited in different tectonic environments. The Paleozoic continental-shelf strata include rocks of Cambrian through Pennsylvanian ages (Permian? unnamed limestone). These strata are predominantly carbonate rocks. Upper Cambrian rocks in the wilderness study area are low- to medium-grade metamorphosed silty carbonate rocks. The Lower to Middle Ordovician Pogonip Group occurs both as low-grade metamorphosed silty carbonate rocks and as brittlely deformed rock in the western part of the area, and the Middle Ordovician Eureka Quartzite occurs as quartzose sandstone. The Upper Ordovician Ely Springs Dolostone, Silurian Laketown Dolostone, Upper Silurian to Lower Devonian Sevy Dolostone, and Middle Devonian Simonson Dolostone compose a thick section of carbonate rocks that are shown combined on plate 1 (unit DSOd). This Ordovician to Devonian dolomitic section is overlain by the thick cliff-forming Middle and Upper Devonian Guilmette Formation that is composed of limestone interlayered with less prevalent dolostone and minor shaley limestone beds. The Upper Devonian and Lower Mississippian Pilot Shale, which is a major gold producing unit in the region, is absent in the wilderness study area because of nondeposition (Poole and others, 1977). The Lower Mississippian Joana Limestone and Lower and Upper Mississippian Chainman Shale are shown combined on plate 1 (unit Mcj). Many occurrences of jasperoid (Lovering, 1972) are along faults within the Joana Limestone or where it is in fault contact with the Chainman Shale. The Upper Mississippian to Pennsylvanian Ely Limestone is gradational with the Chainman Shale.

Paleocene to Eocene nonmarine rocks of the Sheep Pass Formation unconformably overlie Paleozoic strata. Fouch (1979) interpreted the rocks to have been deposited in a lacustrine environment.

Oligocene to Pliocene rocks unconformably overlie Middle Devonian to Eocene rocks. Oligocene and younger volcanic rocks are overlain by and interlayered with Miocene to Pliocene basin-fill sedimentary rocks of the Horse Camp Formation. The volcanic rocks are rhyolitic welded and unwelded tuffaceous rocks that have been subdivided into several different formations (Cook, 1960; Scott, 1965). The distribution of the volcanic units is uneven; some have local sources, whereas other volcanic units occur regionally and have more distant sources (Cook, 1960; Moores and others, 1968).

Quaternary alluvium and colluvium occur as bouldery to sandy debris in stream-channel, valley-fill, pediment-covering, and alluvial-fan deposits.

Metamorphism

Upper Cambrian to Middle Ordovician rocks have been metamorphosed to both low and medium grades. The metamorphic fabric is defined by aligned mineral flakes or by transposed bedding. Fabrics in these rocks indicate that metamorphism occurred by dynamic, regional processes rather than by static contact metamorphism. The only known pluton in the Grant Range occurs in the Troy Canyon mining district (fig. 1); intrusion of the Troy Canyon pluton postdates the metamorphism of country rocks (Hill, 1916). The regionally metamorphosed rocks in the wilderness study area are separated from overlying unmetamorphosed rocks by a low-angle fault.

Structure

Metamorphosed Upper Cambrian and Lower and Middle Ordovician rocks were subjected to Mesozoic ductile deformation. The Mesozoic structures consist predominantly of east-directed minor folds. Six miles south of the wilderness study area, the regional metamorphic fabric in these rocks was deformed into a large, east-vergent, overturned anticline before being intruded by the late Mesozoic (70-million-year-old) Troy Canyon granite pluton (Fryxell, 1984; J.E. Fryxell, written commun., 1985). Dismembered fragments of Mesozoic compressional structures are also present in the form of overturned folds and low-angle faults that duplicate strata in nonmetamorphosed rocks of the wilderness study area.

Cenozoic low-angle and associated minor high-angle extensional faults attenuate the stratigraphic section in the wilderness study area and cut and rotate units from Cambrian to Holocene in age. Major detachment faults occur at the base of Tertiary strata, Mississippian strata, and the Upper and Middle Devonian Guilmette Formation as well as within the Guilmette Formation and the upper part of the Pogonip Group. Metamorphosed Upper Cambrian to Middle Ordovician rocks, which underwent Mesozoic ductile deformation, are juxtaposed against overlying younger, nonmetamorphosed Devonian and Mississippian rocks along a shallow west-dipping detachment fault west of the wilderness study area. Rocks of the upper plate are intensely brecciated, whereas those of the lower plate are not.

Jasperoid breccias (Lovering, 1972) are common along low-angle faults in the Mississippian rocks, and quartz veins are common in steep faults in the Upper Cambrian metamorphic rocks.

Geochemistry

A total of 119 bulk stream-sediment samples, 114 heavy-mineral-concentrate samples derived from stream sediment, 18 spring-water samples, and 8 rock samples were collected from the Riordans Well Wilderness Study Area and analyzed by semiquantitative direct-current arc emission spectrography and atomic-absorption spectrophotometry.

Stream-sediment-sample sites were chosen to provide representative coverage of the study area. The study area was divided into 1-mi^2 (square mile) cells. In each cell, sites were located in first-order or small second-order streams draining areas of about 0.5 to 0.75 mi^2. This sample-density design permits identification of geochemically anomalous areas that may reflect mineralization. At each stream site a composite bulk sediment sample was collected from an approximate 50-ft length of channel. Each sample was passed through a 10-mesh sieve and placed in a cloth sample bag. In the laboratory each sample was passed through an 80-mesh sieve and the fine fraction saved for analysis. This fraction contains clay, silt, fine sand, hydroxides, and organic matter. Large (about 8 pounds) samples for analysis of heavy minerals were collected from sites within the stream channel where heavy minerals were likely to accumulate. These samples were panned and the heavy fractions saved. At the laboratory, the panned concentrates were passed through a 35-mesh sieve and then separated in bromoform (specific gravity 2.8) to remove any remaining light minerals. The remainder was separated into two fractions using a large electromagnet. The most magnetic material (primarily magnetite, ferromagnesian silicates, and iron oxides) was discarded; the least magnetic material (that included zircon, sphene, rutile, sulfates, carbonates, oxides, and sulfides) was hand ground for spectrographic analysis.

Springs were located from topographic maps or identified from the air. At each spring, a 400-mL (milliliter) water sample was collected in a new untreated plastic bottle. Another 60-mL sample was filtered through a 0.45-micrometer filter, acidified with reagent-grade concentrated nitric acid to pH 2, and stored in an acid-rinsed polyethylene bottle. Water temperature and pH were measured at each site.

Rock samples showing evidence of mineralization were collected from outcrops and float. These samples were ground for analysis.

Emission spectrography (Meyers and others, 1961) was used to analyze all bulk-sediment, heavy-mineral-concentrate, and rock samples for 31 elements. Atomic-absorption analysis for arsenic, antimony, and silver was performed on bulk sediment and rock samples to obtain lower detection limits for these elements. Spring-water samples were analyzed for silver, arsenic, lithium, calcium, copper, iron, manganese, potassium, magnesium, molybdenum, sodium, lead, antimony, and zinc using atomic-absorption techniques and for sulfate, fluorine, and chlorine using ion chromatography.

Detection limits and analytical results of chemical analysis of bulk-sediment, heavy-mineral-concentrate, rock, and spring-water samples are in Hofstra and others (1984).

The occurrence of anomalously high concentrations of a certain element or a specific association of elements in a sample may indicate that mineralization is present. The absence of an anomaly does not necessarily mean that a mineral deposit does not exist. The deposit may be too deep or below an impervious layer that prevents transport of elements into the sample medium. Dilution and (or) immobilization of elements in stream sediments and ground water may cause samples collected near mineralized areas to show only background values. In this study, more confidence is assigned to anomalies at sites where two or more elements occur in anomalous concentrations, where there are clusters of sites with anomalous concentrations of elements, or where anomalous concentrations are found in several different sample media. Elements and anions found to be most effective in outlining mineralized areas in this study area are: arsenic, boron, and zinc in bulk stream sediments; bismuth, cobalt, molybdenum, lead, tin, thorium, tungsten, and zinc in heavy-mineral concentrates; arsenic, fluorine, and sulfate in spring water; and silver, arsenic, gold, boron, molybdenum, lead, antimony, and zinc in rock samples.

The Riordans Well Wilderness Study Area is in substantially natural condition, and possible geochemical contamination from roads, ranching, and mining is minimal. Roads are only along the margins of the study area, and contamination from ranching (for example, chemicals added to livestock feed) is possible only at the northern end of the area.

Based on the geochemical survey, three geochemically anomalous areas were identified. In the southeastern part of the study area, near the Wizard and CG lode claims, analyses of 15 bulk stream-sediment and heavy-mineral-concentrate samples show a zonation pattern where sites containing high arsenic (30–40 ppm) and zinc (500–3,000 ppm) concentrations are surrounded by sites containing high boron (100–1,000 ppm), gold (50–60 ppb), silver (0.5–0.65 ppm), arsenic (100–220 ppm), antimony (4–7 ppm), zinc (2,000 ppm), copper (150 ppm), molybdenum (70 ppm), nickel (500 ppm), and chromium (1,000 ppm) concentrations. At lower elevation, 1.5 mi to the southeast, water from a spring that discharges from the contact between alluvium and bedrock has anomalous arsenic values (8 ppb). This element association is characteristic of gold and silver mineralization. The geologic formations that crop out in this area (Guilmette Formation, Joana Limestone, Chainman Shale, and Ely Limestone) are known to be favorable hosts for gold and silver in the surrounding region.

A second anomalous area is along the southwestern boundary of the wilderness study area (pl. 1). Here 13 anomalous heavy-mineral-concentrate samples define a zonation pattern that has tungsten (>100 ppm) and bismuth (>20 ppm) on the west, lead (>300 ppm) and zinc (>500 ppm) in the middle, and tin (>20 ppm), tungsten (>100 ppm), and bismuth (>20 ppm) on the east. A bulk stream-sediment sample from the lead-zinc zone contained anomalous amounts of arsenic (50 ppm). A rock sample from this area contained anomalous concentrations of gold (50 ppb) and lead (70 ppm). The southwestern margin of the wilderness study area is 4 mi north of the part of the Troy mining district from which tungsten from skarns and gold from quartz veins have been mined. The anomalous samples in this area are probably related to mineralization in the adjacent Troy mining district and may outline a northeastern extension of the district.

A heavy-mineral-concentrate sample from near the central-western boundary of the wilderness study area contained anomalous concentrations of molybdenum, and a quartz-carbonate vein sample (float) contained anomalous gold (60 ppb) and lead (70 ppm). This element association suggests tungsten-gold mineralization such as in the Troy mining district.

Geophysics

Regional aeromagnetic and gravity anomaly maps of the Riordans Well Wilderness Study Area and vicinity (figs. 4 and 5) contribute to an understanding of the geologic framework that forms a basis for evaluation of the mineral resource potential. The map area covers both the Riordans Well and adjacent Blue Eagle Wilderness Study Areas as well as contiguous parts of the Grant Range, Horse Range, and Railroad and White River Valleys. Additional information on the geologic interpretation of the map is discussed in a report on the Blue Eagle Wilderness Study Area (Lund and others, 1987).

The aeromagnetic map (fig. 4) was produced by merging data from three surveys: (1) a high-level (11,500-ft) survey of the northwestern part of the Lund 1°x2° quadrangle, flown at 1-mi spacing (U.S. Geological Survey, 1976); (2) a draped (1,000 ft above terrain) survey of the Quinn Canyon Range, flown at 0.5-mi spacing (U.S. Geological Survey, 1979), and (3) a draped (1,000 ft above terrain) special survey of the two study areas, also at 0.5-mile spacing (U.S. Geological Survey, 1985). The International Geomagnetic Reference Field has been removed from all three surveys to yield a residual total magnetic field intensity anomaly map at 1,000-ft drape altitude.

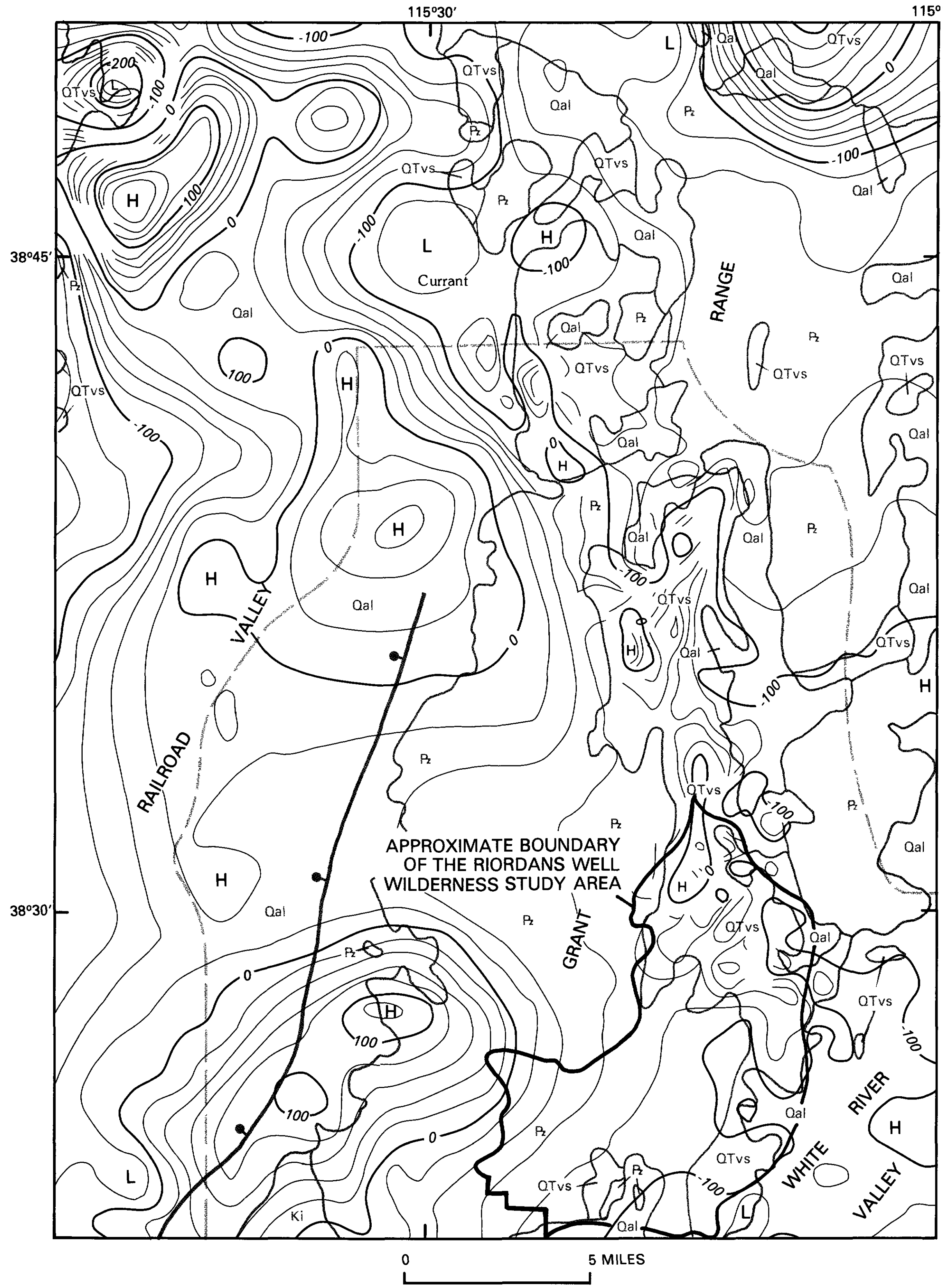

Figure 4 (above and facing page). Residual total-intensity aeromagnetic anomaly map of the Riordans Well Wilderness Study Area and vicinity, Nevada. Average height of survey, 1,000 ft above terrain; International Geomagnetic Reference Field removed; arbitrary datum.

EXPLANATION

-200	**Anomaly contour**—Contour interval 20 nanoteslas
	Boundary of aeromagnetic survey of January 1985
H	**Anomaly high**
L	**Anomaly low**
Qal	**Quaternary alluvium**
QTvs	**Quaternary and Tertiary volcanic and sedimentary rocks**
Kı	**Cretaceous granite of Troy Canyon pluton**
Pz	**Paleozoic rocks**
	Range-front fault—Delineated by gravity gradient (fig.5) and alignment of springs. Bar and ball on downthrown side
	Geologic contact—Generalized from Kleinhampl and Ziony (1985)

Two features of the regional aeromagnetic map (fig. 4) are significant to the Riordans Well Wilderness Study Area. The first is a belt of short-wavelength anomalies, not delineated in detail, that extends southward into the area from the north-northwest and is associated with exposures of strongly magnetized volcanic rocks of Tertiary age. The belt is diffuse in the study area, but to the north, where it crosses the Blue Eagle Wilderness Study Area, its western boundary becomes a steep magnetic gradient that marks a major structural discontinuity in the magnetic basement. The second feature, especially significant to this study, is a broad aeromagnetic high whose eastern margin projects into the wilderness study area from the west. In the western foothills of the Grant Range, this aeromagnetic high is associated with outcrops of the Cretaceous Troy Canyon granite pluton, which is associated with tungsten, base-metal (copper, lead, zinc, molybdenum, and bismuth), gold, and silver deposits. Therefore, the granite can be inferred to extend into the range at depth beneath the exposed Paleozoic carbonate strata. Quartz veins in the carbonate section in this area may be genetically related to the intrusion. The interpreted margin of the intrusion roughly coincides with the southwesternmost border of the study area between Heath and Grant Canyons.

Data for the regional gravity map (fig. 5) were obtained from files of the U.S. Defense Mapping Agency (available through the National Center for Geophysical and Solar-Terrestrial Data, Boulder, CO 80303), augmented by 20 new stations established during November 1985 and April 1986 with the assistance of J.H. Hassemer of the USGS. All values of observed gravity in this data set were reduced at a density of 2.67 grams per cubic centimeter and then terrain corrected by computer to a radius of 100 mi from the gravity station (see Cordell and others (1982) for a description of standard USGS gravity reduction procedures).

The main feature of the Bouguer gravity anomaly map is a steep anomaly gradient delineating the principal range-front fault between the Grant Range and Railroad Valley; as noted in an earlier discussion (Lund and others, 1987), this fault does not appear to offset the magnetic basement. The gravity expression of the Grant Range in a transverse section is strongly asymmetric. This asymmetry reflects the contrast between the north-south-oriented linear uplifted blocks of dense carbonate rocks of the Horse and Grant Ranges and the thick deposits of low-density material that have accumulated in the structural depression of the White River Valley to the east. Volcanic rocks in the wilderness study area (fig. 5) coincide with a weak gravity low between highs associated with the carbonate rocks. In contrast to its magnetic signature here, the volcanic belt is bounded by linear gravity gradients that may represent structural discontinuities. The inferred extension of the Troy Canyon pluton subjacent to the southwestern boundary of the study area is expressed only by a very weak anomaly embayment in the gravity field of the Grant Range.

Finally, limited aeroradiometric data for the wilderness study area are available from surveys of the National Uranium Resource Evaluation program. Flight traverses on those surveys are too widely spaced (3 mi at 400 ft above terrain) to permit meaningful contouring of the results in such a limited area. The data have been examined by J.S. Duval of the USGS. He reported (written commun., 1985) overall low radioactivity within the area, with values of 0–2.0 percent potassium, 0–2.5 ppm equivalent uranium, 2–8 ppm equivalent thorium, and no uranium or thorium anomalies. Moderate potassium anomalies occur over volcanic rocks to the north and east of the wilderness study area boundary.

Mineral and Energy Resources

Replacement and Vein Deposits

Metamorphosed limestone and dolostone commonly contain metal deposits that formed by hydrothermal replacement of the original rock; these deposits are called skarns or metasomatic replacement deposits. Most skarn deposits form near the contact of carbonate rocks with quartz monzonite to granodiorite plutons where contact metamorphism forms calc-silicate minerals in carbonate rocks; alteration and mineralization accompany circulation of hydrothermal fluids. Most valuable skarn deposits contain accessory

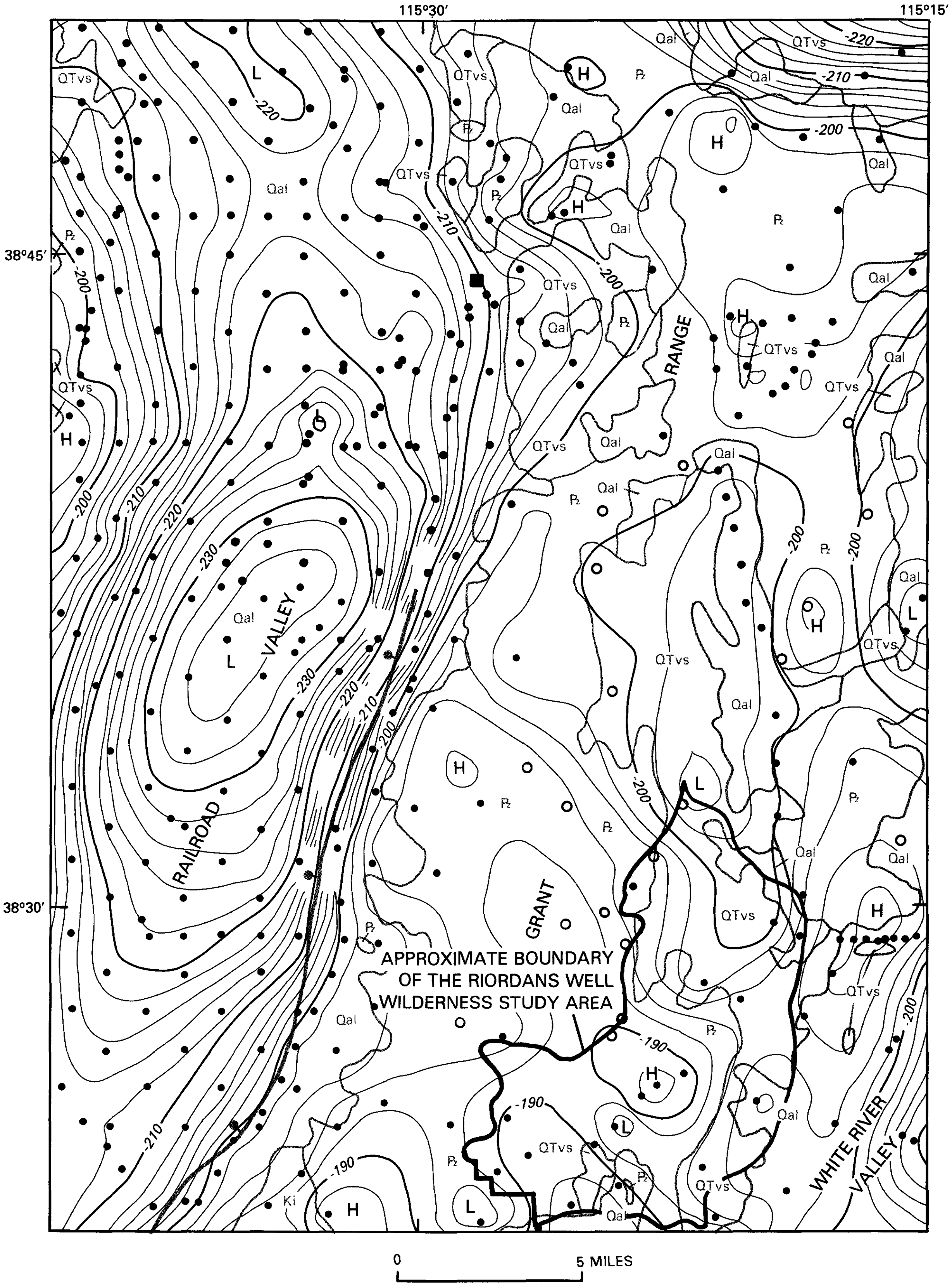

Figure 5 (above and facing page). Complete Bouguer gravity anomaly map of the Riordans Well Wilderness Study Area and vicinity, Nevada. Terrain corrected from digital topography to 100 mi.

EXPLANATION

210	**Complete Bouguer gravity anomaly contour**— Contour interval 2 milligals
H	**Anomaly high**
L	**Anomaly low**
•	**Gravity station**— U.S. Defense Mapping Agency
o	**Gravity station**— This study
Qal	**Quaternary alluvium**
QTvs	**Quaternary and Tertiary volcanic and sedimentary rocks**
Ki	**Cretaceous granite of Troy Canyon pluton**
Pz	**Paleozoic rocks**
	Range-front fault— Delineated by gravity gradient and alignment of springs. Bar and ball on downthrown side.
	Geologic contact— Generalized from Kleinhampl and Ziony (1985)

gold. Both tungsten and polymetallic base-metal sulfide skarns are formed by the same processes. Tungsten skarns may also be characterized by anomalous contents of molybdenum, copper, zinc, or bismuth. Polymetallic base-metal skarns are characterized by anomalous contents of tungsten, copper, lead, zinc, molybdenum, bismuth, and silver. Lead-zinc skarn deposits may form in environments a few miles from a pluton under conditions where fluids traveled along fractures and cooled before deposition of the more soluble elements (Einaudi and others, 1981). Although this hydrothermal-replacement or skarn model seems to be the best model for mineralization in the western parts of the wilderness study area, not all aspects of the geology fit the model.

The western parts of the wilderness study area and the nearby Galena claim block are in the lower plate below the detachment fault that separates regional metamorphosed silty carbonate rocks from unmetamorphosed rocks; the metamorphic rocks are cut by many steep normal faults. Although geophysical data indicate the presence of buried plutonic rocks in this area (see the section on "Geophysics"), the metamorphic character of these rocks is related to regional metamorphism that is older than the Troy Canyon pluton. Thin, discontinuous quartz veins in fractures contain sulfide minerals. The area is characterized by anomalously high values for tungsten, molybdenum, bismuth, lead, zinc, copper, arsenic, silver, and gold in the various sample media (see the section on "Geochemistry").

The western parts of the wilderness study area have several features in common with metal-mineralized skarns: (1) the suite of anomalous elements is similar to that associated with skarns, (2) the sulfide mineralogy is similar to that of skarn deposits, (3) the country rocks are metamorphosed shaley carbonate rocks, and (4) an intermediate-composition pluton is nearby and may extend in the subsurface beneath the wilderness study area.

Deposits in geologic settings similar to those found in the wilderness study area were exploited from 1867 to 1872 in the Troy mining district 4 mi south, from 1911 to at least 1921 in the Willow Creek district 20 mi south (Lincoln, 1923; fig. 1), and during the 1950's at the Terrell and Nye mines in the northern part of the Troy district 3 mi southwest. Only minor contact-metamorphic effects were reported from around the granitic intrusion in these districts. In the Troy and Willow Creek districts, silver, gold, copper, and lead were mined from quartz veins and mineralized fractures that cut both the Troy Canyon granite pluton and the regionally metamorphosed and deformed Cambrian carbonate rocks (Hill, 1916; Kleinhampl and Ziony, 1984). According to Hill (1916), the veins are not related to the minor contact metamorphic effects found in some places near the granite and, generally, the veins have clay gouge along them. The quartz-vein material formed as open-space filling and shows multiple shearing episodes. Some deposits formed as replacement along bedding where movement of fluids may have been restricted by shale-rich layers (Hill, 1916). At the Terrell and Nye mines in the northern Troy mining district, tungsten was mined from metamorphosed carbonate rocks near the margins of the Troy Canyon pluton (Kleinhampl and Ziony, 1984).

Several important indications for skarn-type mineral deposits are absent in the wilderness study area as well as in the deposits in nearby districts. The contact-metamorphic mineral assemblage that would be expected in skarn deposits related to the granite pluton is uncommon or absent. Although a buried pluton is indicated from geophysical data, the nearest exposure of granite is in the Troy district about 4 mi south of the wilderness study area, and thus no direct link occurs between hydrothermal fluids and intrusive rock; deposits in the Troy district are not caused by contact metamorphism associated with the adjacent granite (Hill, 1916). The absolute timing of veins and structures that contain veins is unknown, and more study is necessary to understand the structural setting of the veins as well as to determine if the host structures are old enough to have been the conduits for fluids circulating during emplacement and cooling of the 70-million-year-old pluton.

Because of the several positive indications of mineralization and in spite of unanswered questions about the origin of the mineralizing fluids and the host structures, these western parts of the study area have moderate mineral resource potential for tungsten in hydrothermal replacement deposits, polymetallic base metals (Cu-Pb-Zn-Mo-Bi) in replacement deposits and in quartz veins, and for gold and silver in quartz veins (fig. 2, pl. 1). Some important questions remain concerning: (1) the timing of structural events and mineralization relative to emplacement of the granite pluton, (2) the geometry of structures that contain mineralized rock, and (3) the unexposed extent of the Troy Canyon granite pluton. Without this information, the genesis of deposits in the nearby mining districts cannot be completely understood. The geochemical, geological, and historic mining information give a good but not conclusive indication of the certainty of mineral resource potential (level C, fig. 2, pl. 1).

Disseminated Gold Deposits

Many disseminated gold deposits (Carlin-type) of the Basin-and-Range province are fine-grained, metal-bearing, siliceous replacements of Upper Devonian to Mississippian silty carbonate rocks, commonly associated with jasperoid occurrences. These deposits are thought to have formed by migration of low-temperature hydrothermal fluids along normal-fault conduits at shallow crustal levels. The hydrothermal fluids are interpreted to have been meteoric water probably driven by shallow Tertiary igneous processes. These deposits are geochemically characterized by anomalously high values for the assemblage arsenic, mercury, antimony, and thallium (Radtke and others, 1980).

Jasperoid bodies in the wilderness study area are primarily in the southeastern and eastern parts of the area in complexly faulted Lower Mississippian Joana Limestone and Lower and Upper Mississippian Chainman Shale and are overlain by Oligocene volcanic rocks (pl. 1). The jasperoids are localized along low- and moderate-angle (shovel-shaped) normal-fault zones in the Joana Limestone or Chainman Shale; these faults have also rotated volcanic rocks above the Joana and Chainman interval. The jasperoids in the Joana Limestone are evidence that fluids circulated through the fault systems probably during and after volcanic activity. These jasperoids have anomalously high amounts of arsenic, antimony, and zinc.

Several disseminated gold and silver deposits have been discovered and recently mined in eastern Nevada and provide additional deposit models for comparison with occurrences in the wilderness study area. Deposits at the Alligator Ridge gold mine, White Pine County, about 100 mi north of the wilderness study area, fit the general characteristics of the disseminated gold and silver deposit model. The mine is in the Lower Mississippian and Upper Devonian Pilot Shale (Klessig, 1984). The Taylor mine, on the western side of the Schell Creek Range in White Pine County, about 50 mi northeast of the wilderness study area, consists of a group of disseminated silver deposits in the Guilmette Formation, Pilot Shale, and Joana Limestone. Deposits at both mines are associated with jasperoid occurrences; the source of the gold and silver is not known but may be the carbonaceous shales of the Pilot Shale.

Because of some positive geologic, geochemical, and regional indications of mineralization and the applicability of the disseminated replacement gold-deposit model, the southeastern and eastern parts of the wilderness study area have moderate resource potential for gold (fig. 2). A possibly significant contraindication is the absence of the Lower Mississippian and Upper Devonian Pilot Shale due to nondeposition in the wilderness study area; this unit contains disseminated gold or silver deposits regionally. The favorable geochemical indications of gold mineralization were found along previously prospected jasperoid zones near faults that attenuate stratigraphy between Mississippian and Devonian strata; these jasperoids may only persist to shallow depths (as was suggested for some in the Ely district by Lovering, 1972) and may be relatively small, isolated features. Because the size and extent of the hydrothermal systems associated with the outcropping jasperoid occurrences are unknown, but positive indications of mineralization are present, the available information provides good but not conclusive certainty of the level of mineral resource potential (certainty level C, fig. 2, pl. 1).

Oil and Gas Resources

Models for petroleum (oil and gas) occurrences in central Nevada are based on five oil fields that have been located in Railroad Valley west of the wilderness study area (fig. 1). Source rocks for these fields are the Paleocene to Eocene Sheep Pass Formation for the Currant and Eagle Springs fields and the upper Mississippian Chainman Shale for the Trap Spring, Grant Canyon, and Bacon Flat fields; two periods of oil generation occurred. Three types of reservoir rocks are present in Railroad Valley: (1) Paleogene sedimentary and volcanic rocks in the Trap Spring, Eagle Springs, and Currant fields; (2) Paleozoic dolostone and sandstone in the Bacon Flat and Grant Canyon fields; and (3) fractured Ordovician Eureka Quartzite in the Soda Springs No. 1 well, 1 mi south of the Eagle Springs field. Oil migrated into the valley during the Quaternary by means of shovel-shaped normal faults (that flatten at depth) that bound the Grant Range and by buried alluvial fans that cover the faults; these young faults were conduits for both newly generated oil and for oil from older traps (Poole and Claypool, 1984).

The wilderness study area is rated as having high energy resource potential for petroleum based on thermal maturation of source beds and the occurrence of producing oil fields in the adjacent Railroad Valley wells (Sandberg, 1983). Both Sheep Pass Formation and Chainman Shale source beds crop out in the wilderness study area. The Chainman Shale contains oil in outcrop north of the wilderness study area (Poole and Claypool, 1984) and is at optimum thermal maturity for oil and gas generation where it occurs in the wilderness study area (Sandberg, 1983). Many structural conduits for migration of petroleum are present as well as structures that would be suitable traps; the geometry of structural features allows oil of either age to migrate into traps in rocks of any age, as is demonstrated in the Railroad Valley fields. The range-bounding normal faults are the youngest and most extensive faults; these cut earlier low-angle and associated steeper normal-fault systems and form the main conduits for migration of fluids into traps both in Railroad Valley and possibly in other structural settings in the Grant Range. The likelihood, from geophysical information (see above), that these range-front faults become shallow with depth westward beneath Railroad Valley and separate thermally mature Paleozoic source rocks from metamorphosed older(?) sedimentary rocks indicates the possibility of the same favorable conditions for oil occurring in the wilderness study area.

Several aspects of the geology that are important to the resource potential for petroleum in the wilderness study area are not well known. The complexity of normal faulting makes it difficult to project the position of structures at depth beneath younger cover, and the migration capacity of particular faults and fault systems has not been established. The shape, depth of shallowing, orientation, and relative timing of the range-bounding faults are only partly modeled from seismic studies (Effimoff and Pinezich, 1981) and the present geologic mapping and geophysical interpretation. The information available gives a good indication of the high level of petroleum resource potential (certainty level C, fig. 2, pl. 1). Unanswered questions about petroleum migration and traps may indicate that the wilderness study area may be a better source area for oil and gas than a reservoir area.

Other Energy Resources

There are no known coal-bearing beds in the vicinity of the wilderness study area. The area has a low potential for the occurrence of coal resources (certainty level B, pl. 1).

Some history of uranium prospecting north of the wilderness study area was found during the mineral survey of the Blue Eagle Wilderness Study Area (Lund and others, 1987). However, the units of interest are younger than those found in the Riordans Well Wilderness Study Area and have been eroded or were never deposited here. The wilderness study area has a low potential for the occurrence of uranium (certainty level B, pl. 1).

No thermal springs are known in the wilderness study area. The only known warm springs in the vicinity occur along range-bounding faults in Railroad Valley (pl. 1) and possibly along similar faults in the White River Valley. The wilderness study area has a low potential for geothermal energy resources (certainty level B, pl. 1).

Other Metal and Nonmetal Mineral Resources

The geochemical survey did not indicate the presence of anomalously high values for metals not considered above, no other appropriate deposit models currently fit the geologic setting, and no history of production for the metals was found in the region. Therefore, other metals have a low mineral resource potential in the wilderness study area (certainty level B, pl. 1).

Magnesite deposits are known outside of the wilderness study area about 15 mi north of the area of figure 1. These deposits are in a white volcanic tuff unit (Faust and Callahan, 1948) that does not crop out in the wilderness study area (Moores and others, 1968) due to nondeposition or erosion. Therefore, magnesite is considered to have low mineral resource potential in the study area with certainty level B (pl. 1).

There is no history of production of high-purity limestone or dolostone in the Riordans Well Wilderness Study Area or its vicinity. Although no chemical data are available, the limestone and dolostone, which are abundantly available in the wilderness study area, may contain too much clay and silt to be of high purity. Therefore, the mineral resource potential for high-purity limestone or dolostone in the wilderness study area is low (certainty level B, pl. 1).

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APPENDIX

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 unlikely. 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 a 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 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.

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

LEVEL OF RESOURCE POTENTIAL →

<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 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.

Abstracted with minor modifications from:

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

Taylor, R. B., Stoneman, R. J., and Marsh, S. P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40–42.

Goudarzi, G. H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–0787, p. 7, 8.

RESOURCE / RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (or)	
	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 in this report

EON	ERA	PERIOD		EPOCH	BOUNDARY AGE IN MILLION YEARS
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 m.y. also called Precambrian, a time term without specific rank.

[2] Informal time term without specific rank.

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