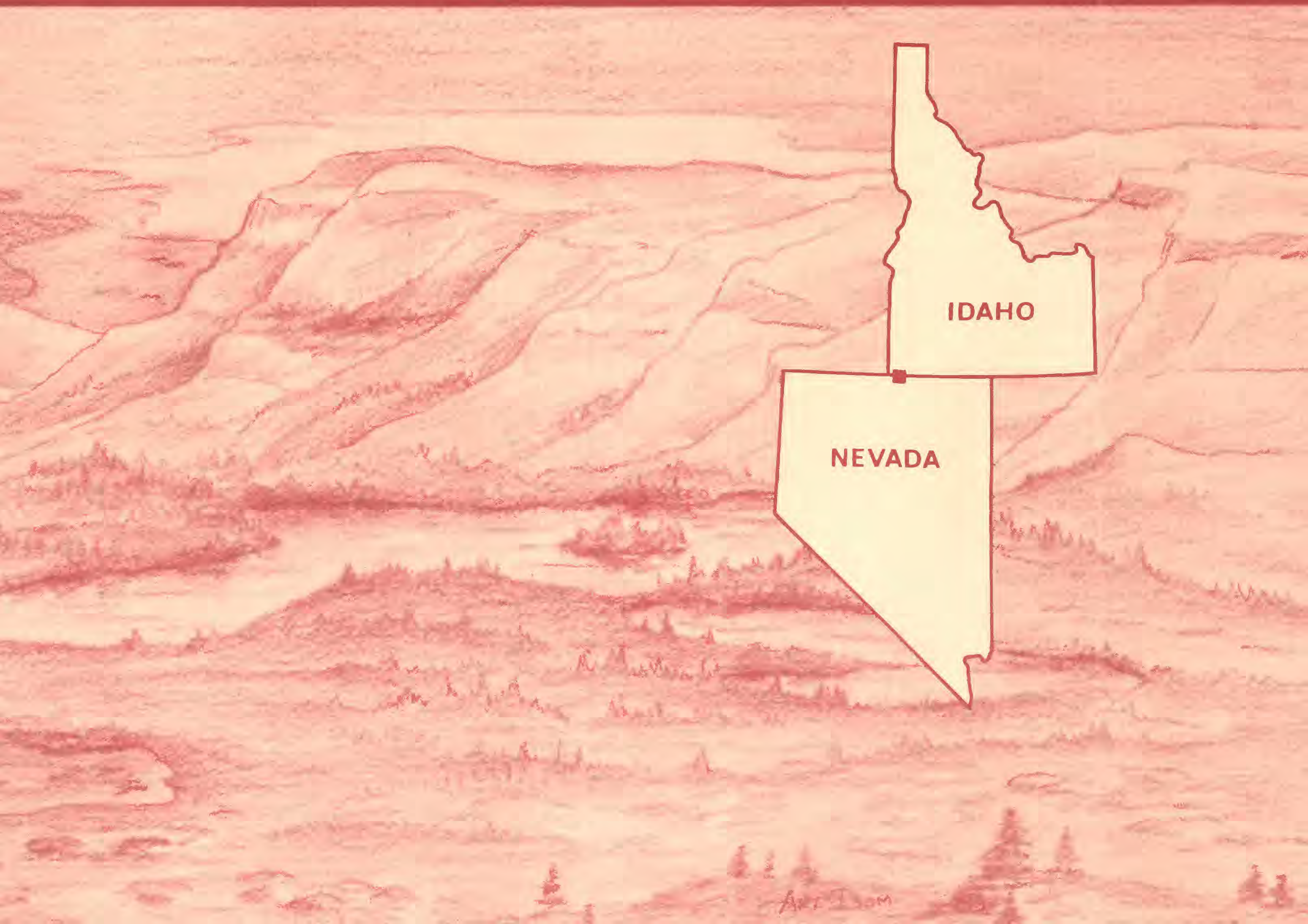
Mineral Resources of the Owyhee Canyon and South Fork Owyhee River Wilderness Study Areas, Elko County, Nevada, and Owyhee County, Idaho

U.S. GEOLOGICAL SURVEY BULLETIN 1719–F



Chapter F

Mineral Resources of the Owyhee Canyon and South Fork Owyhee River Wilderness Study Areas, Elko County, Nevada, and Owyhee County, Idaho

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U.S. GEOLOGICAL SURVEY BULLETIN 1719

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
OWYHEE RIVER REGION, IDAHO AND 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 mineral surveys of the Owyhee Canyon (NV–010–106) and South Fork Owyhee River (NV–010–103A and ID–016–053) Wilderness Study Areas, Elko County, Nevada, and Owyhee County, Idaho.

CONTENTS

PLATE

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FIGURES

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
OWYHEE RIVER REGION, IDAHO AND NEVADA

Mineral Resources of the Owyhee Canyon and South Fork Owyhee River Wilderness Study Areas, Elko County, Nevada, and Owyhee County, Idaho

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SUMMARY

Three U.S. Bureau of Land Management (BLM) wilderness study areas comprise approximately 61,135 acres of Tertiary volcanic rocks exposed along the South Fork of the Owyhee River in northeastern Nevada and southwestern Idaho. From south to north, the Owyhee Canyon (NV–010–106, 13,525 acres)[1] and South Fork Owyhee River (Nevada part, NV–010–103A, 5,180 acres, and Idaho part, ID–016–053, 42,430 acres) Wilderness Study Areas extend for 38 mi (miles) through Elko County, Nev., and Owyhee County, Idaho (fig. 1). The southern tip of the study region (the area including all three study areas) is about 40 mi west of Mountain City, Nev., and approximately 60 mi east of McDermitt, Nev. Joint mineral resource studies of the wilderness study areas were done in 1984–85 by the U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (USBM). The USGS studied the total acreage of the three study areas, that is, 21,875 acres of Owyhee Canyon (NV–010–106), 7,842 acres of South Fork Owyhee River (NV–010–103A), and 42,510 acres of South Fork Owyhee River (ID–016–053). This report, however, presents only the joint results of surveys by the USGS and the USBM on the lesser acreages mentioned previously. The studies showed that all three areas have low potential for undiscovered resources of all metals and nonmetals, oil, gas, coal, and geothermal energy (fig. 2). There are no identified resources in any of the wilderness study areas.

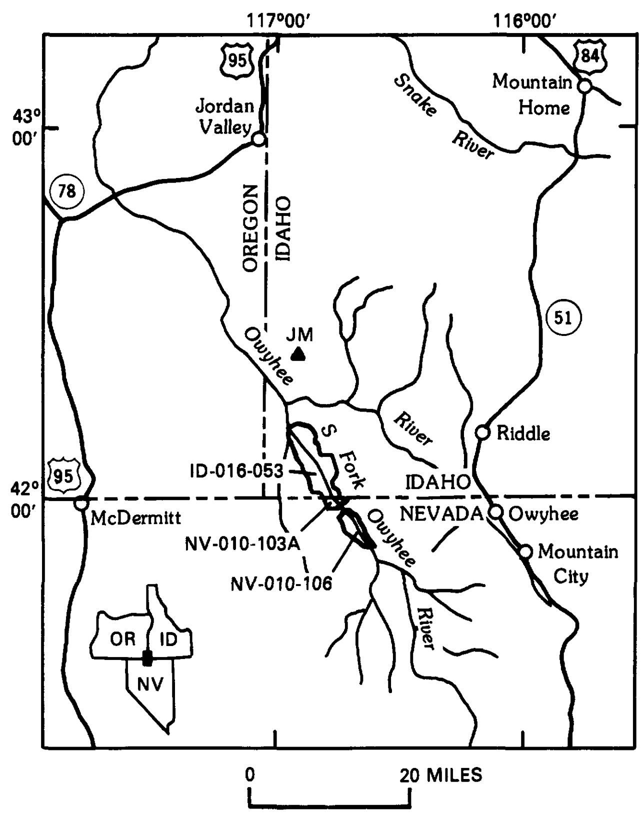

Figure 1. Index map showing location of the Owyhee Canyon (NV-010–106), and South Fork Owyhee River (Nevada part, NV-010–103A; Idaho part, ID-016–053) Wilderness Study Areas. JM, Juniper Mountain volcanic center of Ekren and others (1984) (modified from Kuntz and others, 1986).

[1]The Owyhee Canyon Wilderness Study Area described in this report is distinct from the Owyhee Canyon Wilderness Study Area in Oregon (OR–003–195), which is described in Bulletin 1719–E in this volume.

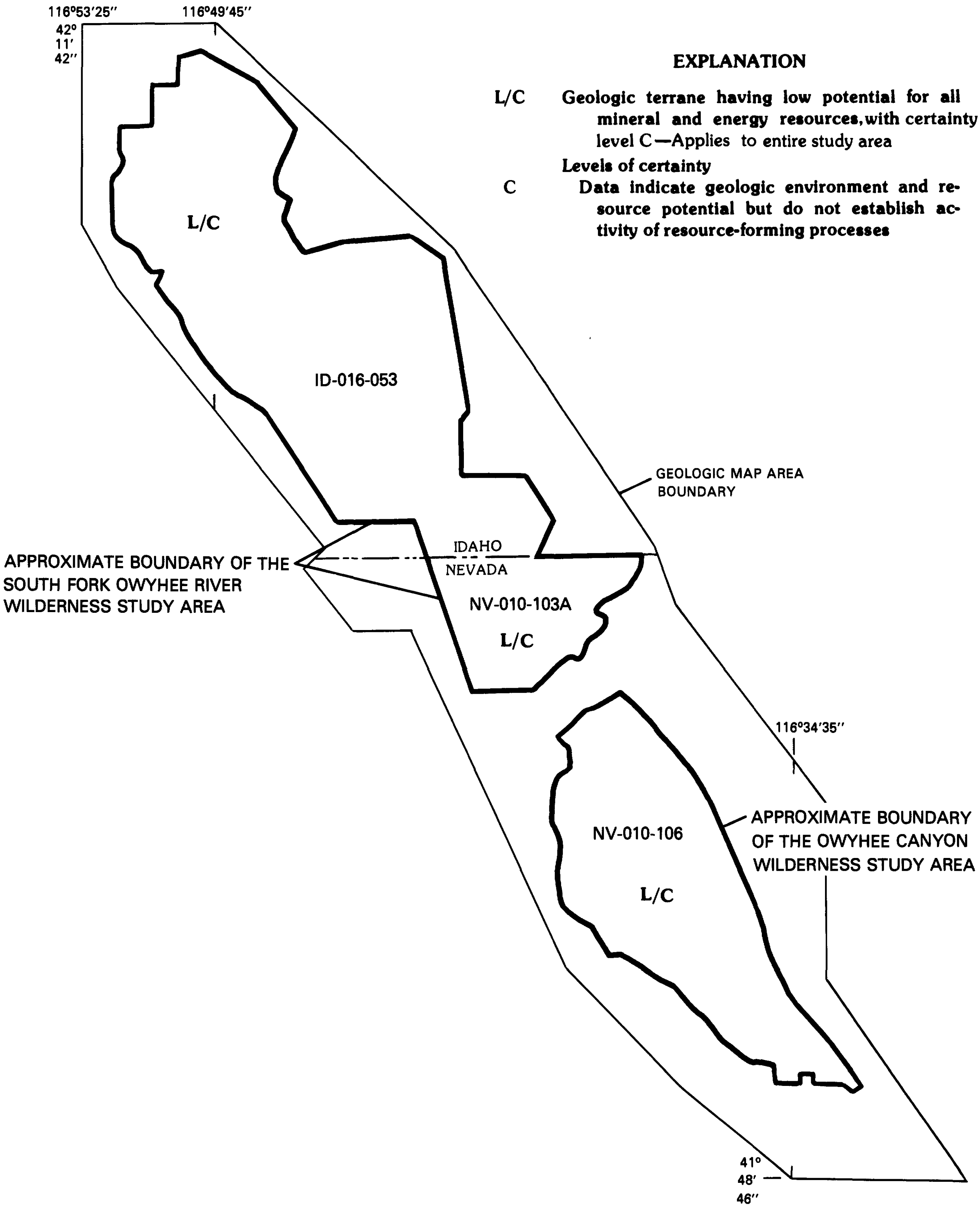

Figure 2. Mineral resource potential map of the Owyhee Canyon and South Fork Owyhee River Wilderness Study Areas (NV-010–106, NV-010–103A, and ID-016–053). No geologic terrane having high or moderate resource potential for any commodity was identified by this study.

The wilderness study areas are on the Owyhee Upland, an extensive volcanic plateau bounded by the Columbia River Plateau, the Snake River Plain, and the Great Basin physiographic-volcanotectonic provinces. The South Fork of the Owyhee River has cut a 400- to 800-ft- (feet) deep channel through basaltic lava flows that cap the plateau. These basalts (fine-grained, dark-colored mafic igneous rocks composed chiefly of calcic plagioclase and clinopyroxene), correlative to the Banbury Basalt to the north and east, are informally called the "basalt of Devil's Corral" in this report. The basalts are gray to black, fresh to slightly weathered, and contain phenocrysts of plagioclase and olivine. Chemically, the basalts are characterized by low potassium and high titanium and are intermediate in composition between typical Snake River Plain basalts and Great Basin basalts (Hart, 1985). The basalts were erupted intermittently between about 10 and 6 Ma (million years ago) (Hart and others, 1984). Tuffaceous sedimentary rocks (many are very poorly consolidated) derived from older rhyolitic volcanics define the unconformable base of the basalt of Devil's Corral.

Rhyolitic tuff units approximately 14 million years old stratigraphically underlie the basalt of Devil's Corral. These were erupted from the Juniper Mountain volcanic center (Ekren and others, 1984) north of the study region. The upper and lower lobes of the tuff of Juniper Mountain, which consist of ash-flow rhyolite tuff (consolidated pyroclastic igneous rock high in silica content deposited by an ash flow or gaseous cloud), and the Swisher Mountain Tuff, which consists of variably welded ash-flows and flow breccias (breccias formed contemporaneously with the movement of a lava flow), are well exposed in the northern part of the South Fork Owyhee River Wilderness Study Area.

Within the Owyhee Canyon and the Nevada part of the South Fork Owyhee River Wilderness Study Area, the rhyolites underlying the basalt of Devil's Corral are exposed in only a few places and constitute less than 10 percent of the area. In the Idaho part of the South Fork Owyhee River Wilderness Study Area, exposed areas of rhyolite and basalt are about equal. The Swisher Mountain Tuff forms many picturesque spires along the inner canyon where the rock has weathered along vertical cooling joints.

Blocky basaltic talus and slabby-weathering rhyolites that could be used as dimension stone occur throughout the study region. However, none have unique or favorable properties that would make them preferable to other, more accessible deposits closer to markets.

No anomalous concentrations of elements were found in samples from the Owyhee Canyon (NV–010–106) and the Nevada part of the South Fork Owyhee River (NV–010–103A) Wilderness Study Areas, with the exception of one sample that contained 500 ppm (parts per million) lead. The single occurrence of lead in association with high calcium and magnesium but without detectable amounts of other elements associated with base-metal (copper, lead, zinc) mineralization may possibly indicate the presence of mineralized calcite and barite veins in the Tertiary rhyolitic volcanic rocks. Minor amounts of gold were found by panning material from sand and gravel deposits, but the occurrences are too low in grade and too small in volume to support commercial placer operations.

Anomalous amounts of tin, barium, molybdenum, and copper were detected in selected samples from the Idaho part of the South Fork Owyhee River Wilderness Study Area (ID–016–053). Four nonmagnetic heavy-mineral-concentrate samples and one sediment sample contained anomalous amounts of tin, but the mineral resource potential is rated low. Five nonmagnetic concentrate samples contained greater than 1 percent barium, which was determined to be present in the form of barite ($BaSO_4$). Anomalous values for molybdenum were determined for samples from a tributary to the South Fork of the Owyhee River at the northern end of the study area. The source of the molybdenum is not certain. In one nonmagnetic heavy-mineral-concentrate sample from the northern border of the study area, 200 ppm (parts per million) copper was detected. No discrete copper minerals were identified.

Secondary silica enrichment is common in the rhyolites; veins and vugs filled with chalcedony and common opal are present locally. A very small proportion of the chalcedony and opal are of gemstone quality. Only two abandoned mining claims (the Owyhee No.'s 1 and 2) located in 1939, possibly for these minerals, are known (pl. 1), and the total value of chalcedony and opal recovered within the wilderness study areas is estimated at about $100. About 1 mi outside the northernmost wilderness study area, the Lu-Lew prospect (pl. 1) annually yields small amounts of similar, but somewhat higher quality, chalcedony and opal-chalcedony laminates. The Lu-Lew area shows some evidence for metallic-resource-forming processes and is classified as having a low mineral resource potential for gold, silver, and mercury (Ach and others, 1986). The claims inside the study region, however, do not show any evidence of metallic minerals.

Regionally, zeolites occur in altered rhyolite and tuffaceous sedimentary rocks, and diatomite occurs in lacustrine sedimentary rocks. However, similar occurrences were not noted in such rocks between the rhyolites and basalts in the three wilderness study areas. Oil and gas leases cover large areas of the study region, but no resources have been identified, and no coal deposits are known. Petroleum potential for all three wilderness study areas was rated "zero to low" by Sandberg (1983a, b). No thermal waters are known within the study region. Tertiary volcanic rocks exposed in the Owyhee Canyon and South Fork Owyhee River Wilderness Study Areas show low potential for all energy and mineral resources.

INTRODUCTION

The Owyhee Canyon (NV–010–106) and South Fork Owyhee River (NV–010–103A and ID–016–053) Wilderness Study Areas are in northeastern Nevada and southwestern Idaho (fig. 1). They extend for 38 mi along the northwest-flowing South Fork of the Owyhee River and its canyon and adjoining upland for about 0.25–3.5 mi on either side. The Owyhee Canyon (13,525 acres) and the Nevada part of the South Fork Owyhee River (5,180 acres) Wilderness Study Areas are in Elko County, Nev., and the Idaho part of the South Fork Owyhee River Wilderness Study Area covers 42,430 acres in Owyhee County, Idaho. Because these three wilderness study areas are treated together in this report, they will be collectively referred to as the "study region," unless otherwise specified.

Access from Mountain City, Nev., is westerly approximately 42 mi by dirt and gravel roads to the southeastern boundary of the study region (fig. 1). The east-central part of the study region may be reached by 32 mi of dirt roads from Owyhee, Nev. Dirt roads bound most of the eastern and western parts of the study region. The western part can be reached during drier times of the year by fording the river just south of the 45 Ranch, at the northern tip of the study region. Other access to the western part of the wilderness study areas is by dirt roads easterly 62 mi from McDermitt, Nev.

Within the study region, the terrain is flat to gently rolling, having an average elevation of about 5,200 ft, except where the South Fork of the Owyhee River and its tributaries have incised deep canyons. The highest point is Bull Camp Butte (5,394 ft), a basaltic shield volcano near the Idaho-Nevada state line. The lowest point (4,355 ft) is on the South Fork of the Owyhee River at the northwest boundary of the study region. Sagebrush, desert grasses, and a few junipers cover the region, which receives an average of less than 10 in. (inches) of precipitation per year.

The southern part of the study region is characterized by a canyon-within-a-canyon topography. Tertiary basalt flows form a flat plateau, from which a talus slope leads to an inner bench. The channel of the South Fork of the Owyhee River drops sharply as much as 200 ft from the bench, and there is as much as 800 ft of total relief from the plateau. A few broad, convex shield volcanoes (about 1 mi in diameter) dot the upper plateau.

In the northern part of the study region, older Tertiary rhyolitic volcanic rocks are better exposed beneath the veneer of basalt. Many picturesque pinnacles crop out along the inner canyon where rhyolite is weathering along vertical cooling joints.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and is the product of several separate studies by the U.S. Bureau of Mines and the U.S. Geological Survey. 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. Mineral resource potential is the likelihood of occurrence of undiscovered concentrations of metals and nonmetals, of unappraised 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), which is also shown in the appendix of this report.

Investigations by the U.S. Bureau of Mines

The USBM conducted studies of the wilderness study areas in 1984. They researched the mining and exploration history, appraised the chalcedony-opal deposits and construction-material deposits, and searched within and adjacent to the study region for claims, both recorded and unrecorded, prospects, and mineralized areas. Their results are presented here and in open-file reports by Capstick and Buehler (1986) and by Mayerle and Gabby (1986).

Investigations by the U.S. Geological Survey

The USGS conducted a mineral resource assessment of the Owyhee Canyon and the two South Fork Owyhee River Wilderness Study Areas during the summers of 1984–85. The work consisted of geologic mapping, geochemical sampling, petrographic and geochemical analysis, and review of previous studies (geologic maps, geochemical and geophysical data, geochronology, and other geologic studies) published on the region. Rock, stream-sediment, and heavy-mineral-concentrate samples from stream sediment were collected for the geochemical analysis. Geochemical studies were done by Harlan Barton for NV–010–106 and NV–010–103A, and similar studies were done for ID–016–053 by H.D. King.

Recent geological studies (by the USGS as well as others) of the region including the wilderness study areas include those by Hope and Coats (1976), Ekren and others (1981, 1984), and various authors in Bonnichsen and Breckenridge (1982). Studies of the geology, energy and mineral (GEM) resources were made by Mathews and Blackburn (1983a, 1983b). Several reports on uranium potential were prepared for the U.S. Department of Energy during their National Uranium Resource Evaluation (NURE) program by Geodata International, Inc. (1980), Berry and others (1982), and Union Carbide Corporation (1982).

Acknowledgments.—The authors are grateful to Ben Glanville, owner of the 45 Ranch; Jim Polkinghorn, manager of the Petan Ranch, and to Sonny and Judy Smith for providing historical and access information, and for their many courtesies. Tom Selner, BLM Range Conservationist, provided aerial photographs and much useful data, and John Benedict, BLM Outdoor Recreation Planner, guided a raft trip down the South Fork of the Owyhee River and provided useful information.

GEOLOGIC SETTING

The study region is on the Owyhee Upland, an extensive volcanic plateau at the intersection of the Columbia River Plateau, the Great Basin, and the Snake River Plain physiographic-volcanotectonic provinces. The Great Basin is a tectonically active continental depression centered in Nevada, covered in part by Tertiary volcanic rocks (Christiansen and McKee, 1978) (see geologic time chart in appendix). The Snake River Plain is a broad, arcuate downwarp that is filled with Tertiary and younger volcanic rocks (Kirkham, 1931) extending across south-central Idaho. The topographic low of the western Snake River Plain gradually rises to become the Owyhee Plateau to the southwest, along a linear northwesterly structural trend. Formation of the Great Basin and Snake River Plain provinces is believed to have been initiated by complex plate interactions between the Pacific and North American plates between 17 and 14 Ma (Livaccari, 1979; Christiansen and McKee, 1978; Suppe and others, 1975; Noble, 1972; Atwater, 1970; and many others).

The Owyhee Upland is characterized by rhyolite-basalt volcanism similar to the Snake River Plain and Great Basin provinces (Hart, 1985; Leeman, 1982). The plateau is underlain by Miocene rhyolitic rocks that range from 13.8 to 9.4 million years old (Ekren and others, 1984). The rhyolitic rocks, which were originally mapped as, and are correlative to, the Idavada Volcanics, are predominantly densely welded rhyolitic ash-flow tuffs as defined by Malde and Powers (1962, p. 1204). Detailed volcanological studies (Ekren and others, 1982, 1984; Bonnichsen, 1982) have since led to further definition of rhyolitic volcanic rocks of the region. The lower lobes of the tuff of Juniper Mountain (unit Tjm), the Swisher Mountain Tuff, and vitrophyres (glassy rocks) approximately 14 million years old have been mapped in and adjacent to the study areas (Ekren and others, 1981, 1984; this study). These deposits were erupted from the Juniper Mountain volcanic center of Ekren and others (1981, 1982, 1984), approximately 20 mi north of the study region, on the Owyhee Plateau (fig. 1).

The rhyolites are overlain by tuffaceous sediments (unit Tts) and by basalts, which were erupted between 10 and 6 million years ago and cap the Owyhee Upland (Hart and others, 1984). These basalts were previously mapped as Banbury Basalt on all known published maps of the region (Ekren and others, 1981, 1984; Stewart and Carlson, 1976; Hope and Coats, 1976; Coats, 1968; and others). However, the informal name "basalt of Devil's Corral" is used here for reasons discussed in the geology section of this report. The uppermost basalt flows, called "rim basalts" (unit Tbr), distinctive cliff formers at the lip of the upper plateau, apparently issued from shield volcanoes in the region. The shield volcanoes have slopes of only a few degrees and rise a few hundred feet above the surrounding basaltic plateau. Many thin basalt flows exposed below the rim basalt are called "canyon basalt" (unit Tbc).

APPRAISAL OF IDENTIFIED RESOURCES

By Donald O. Capstick, Ronald T. Mayerle, Alan R. Buehler, and Peter N. Gabby
U.S. Bureau of Mines

Present Study

The USBM study included library research and perusal of Owyhee County, Idaho, Elko County, Nev., and BLM mining and mineral lease records. USBM and other records were searched and pertinent data compiled. Field work involved searches for all prospects and claims indicated by pre-field studies to be within the study areas and vicinity. Those found were examined and sampled. In addition, ground and aerial reconnaissance was done in areas of obvious rock alteration to check for possible mining-related activities.

During the field study, 25 rock, 4 alluvial (placer), and 10 soil samples were collected in the Idaho part of the South Fork Owyhee River Wilderness Study Area, 10 placer samples were collected in the Nevada part, and 2 placer samples were collected in the Owyhee Canyon Wilderness Study Area. Rock samples were of four types: (1) chip—a regular series of rock chips taken in a continuous line across a mineralized zone or other exposure; (2) random chip—an unsystematic series of chips taken from an exposure of apparently homogeneous rock; (3) grab—rock pieces taken unsystematically from a dump or from float (loose rock lying on the ground); and (4) select—pieces of rock chosen, generally from the apparently best mineralized parts of a pile or exposure or of any particular fraction (for example, quartz, host rock) or from the best pieces of float. Placer samples were either (1) reconnaissance samples of surficial sand and gravel, generally one level 14-in. panful partially concentrated on site to check for the presence of gold or other heavy minerals in placers, or (2) channel samples taken continuously down a cleaned, nearly vertical bank or pit wall and partially concentrated by panning. Soil samples were of red, limonite-stained, clayey soil at the prospects.

Rock samples were analyzed for gold and silver by fire assay, for arsenic and antimony by atomic absorption, and for mercury by one of several methods. At least one sample from each locality was analyzed for 40 elements by semiquantitative emission spectrography to detect unsuspected elements of possible significance. Petrographic examinations were performed to identify selected rock types, alteration suites, and mineral assemblages. Field concentrations of placer samples were further concentrated on a laboratory-size Wilfley table. Resulting heavy-mineral fractions were scanned with a binocular microscope to determine heavy-mineral content. All visible gold consisted of fine particles and was recovered by amalgamation. Concentrates were also checked for radioactivity and fluorescence. Analyses are on file with the Western Field Operations Center of the U.S. Bureau of Mines, E. 360 Third Avenue, Spokane, WA 99202.

Prospects and Mineralized Areas

Silicified outcrops containing chalcedony (cryptocrystalline quartz) and common opal (a hydrated, amorphous form of silicon dioxide) occur along the contact between rhyolite and overlying lacustrine tuffs and tuffaceous sedimentary rocks in the Idaho part of the South Fork Owyhee River Wilderness Study Area. Three sites examined in the study area and the Lu-Lew prospect just to the north contain silicified outcrops in the lower strata of the sedimentary rocks or in the upper 30 ft of the rhyolite. Another site in the area contains a silicified outcrop associated with a fault or crushed zone in the upper part of the rhyolite. The opal and chalcedony occur as botryoidal linings or as fillings in vugs, fractures, or porous layers in the silicified outcrops. Several of the sites have outcrops of leached rhyolite and opaline material and areas of bright-red, limonite-stained, clayey soil adjacent to, or as haloes around, intermittent cold springs or seeps. The location of the silicified outcrops along or near the upper rhyolite rock contacts or in faults and crushed zones (obvious ground-water channel ways) may indicate that the silica was dissolved from the overlying permeable tuffaceous sedimentary rocks, transported downward, and precipitated by cold meteoric water.

Silicified outcrops can be indicators of disseminated precious-metal deposits, a type of deposit formed by deposition from hydrothermal fluids. Regionally, a number of these deposits occur in association with felsic (rhyolitic-dacitic) volcanic rocks similar to those in the Idaho part of the South Fork Owyhee River Wilderness Study Area. Although the silicified outcrops show little evidence of having formed from hydrothermal fluids, samples from these outcrops were assayed for gold and silver, as well as for arsenic, antimony, and mercury, to check for the possibility of disseminated precious-metal deposits. No anomalous concentrations of these elements were found.

The study areas and adjacent region have no history of mining other than minor, unrecorded production of chalcedony and opal-chalcedony laminates suitable for gemstones or mineral specimens. Chalcedony is a hard and durable form of quartz that may be stained by iron, manganese, or other elements producing various attractive colors and patterns. Good-quality material is commonly sold to rock shops or lapidary supply companies, generally for use as gemstones (typically for belt buckles, bolo-ties, bookends, and carvings), mineral specimens, or resale to lapidary hobbyists. The value of the material is based on (1) the ease of cutting and polishing; (2) the amount of wasted material; (3) the brightness, intensity, translucency, and variety of the colors and their patterns; (4) the form, size, and finish of the completed jewelry or mineral specimens; and (5) fashion and demand. All production came from properties in or adjacent to the northern part of the South Fork Owyhee River Wilderness Study Area. Of these, only the Lu-Lew prospect, which is outside the study area, is currently claimed. This prospect probably has produced several hundred dollars worth of material during the last several years. Thunder eggs (fist-size, in part hollow, spherical aggregates of chalcedony), prized as mineral specimens, are plentiful on the surface of the Lu-Lew prospect and account for part of the production from this property. Chalcedony and common opal may have been recovered from three prospects within the Idaho part of the South Fork Owyhee River Wilderness Study Area. Value of total production from loose surface rock or small pits is estimated at about $100.

Common opal is softer than quartz, brittle, and not rare. However, some of the opal found adjacent to the South Fork Owyhee River Wilderness Study Area forms layers and fillings in vugs and fractures and is interbedded with chalcedony. Where the resulting colors are attractive, the opaline laminate may have commercial value.

Two abandoned claims (Owyhee prospect located in 1939) were examined in the northern part of the South Fork Owyhee River Wilderness Study Area. This prospect contains minor amounts of chalcedony and common opal, but may have been located for precious metals. Locations and detailed descriptions of prospects and placer sample localities are given by Capstick and Buehler (1986) and Mayerle and Gabby (1986) and are shown on plate 1.

The minerals at all the prospects are similar. The chalcedony is generally translucent to dull gray, milky white, or tan. The common opal is generally light tan and opaque. The lack of bright and interesting colors and patterns in the minerals limits their value and marketability. Any better quality material that might occur would need to be selectively mined by hand. The material would probably be mined only for recreation by hobbyists.

Sand and gravel deposits along the South Fork of the Owyhee River and its tributaries were examined for gold and heavy minerals. Of 14 placer samples, 13 contained gold; values ranged from $0.01 to $0.06/yd^3 (dollars per cubic yard) in 12 samples and was $0.75/yd^3 in the other (at a gold price of $350/ounce). The gold in each sample was very fine, and amalgamation was used to recover it.

The source of the placer gold in sand and gravel in the study region could not be determined; it probably came from known gold-bearing areas at the head of the South Fork of the Owyhee River, in north-central Nevada. The placer deposits are too small and low in grade to be of commercial value. The sand and gravel deposits are suitable for aggregate uses but cannot compete with larger deposits closer to markets. Volcanic rocks that might be used as dimension stone are widespread within the study region, but lack unique properties that would make them preferable to more accessible deposits.

Regionally, zeolites occur in altered rhyolites, and diatomite occurs in lacustrine sedimentary rocks. Although deposits of these minerals are nearby (Buehler and Capstick, 1985) and in a related geologic environment, no occurrences of zeolite or diatomite were found in the study region.

Oil and gas leases and lease applications cover large portions of the study region, but no resources have been identified.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Eugene E. Foord, Michael J. Luessen, Dirk S. Hovorka, Joseph L. Plesha, V. J. S. Grauch, Harlan Barton, and Harley D. King
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Introduction

The USGS study was composed of three separately conducted phases. The findings of each phase are presented separately in this section.

Geologic mapping within and adjacent to the three wilderness study areas conducted during the summer of 1985 by E.E. Foord, M.J. Luessen, and D.S. Hovorka included collection of 80 rock samples to determine rock geochemistry. Forty of the samples were analyzed by X-ray fluorescence spectrometry for major oxides. Fluorine and ferrous-ferric iron were determined on 20 of those 40 samples. Whole-rock, six-step semiquantitative emission spectrographic analyses (Myers and others, 1961) were performed on 47 samples. Forty-four samples were examined petrographically. Results of these analyses are summarized in the geology section of this report.

A geochemical survey of the study region consisted of collection of 59 stream-sediment samples and 84 heavy-mineral concentrates in 1984 by Harlan Barton, H.D. King, and other USGS personnel. Five additional panned stream-sediment samples were collected by D.S. Horvorka and M.J. Luessen of the USGS. Emission-spectrographic elemental geochemical analyses (Myers and others, 1961) were done on these samples to look for any anomalous concentrations that might be related to mineral deposits.

V.J.S. Grauch and J.L. Plesha prepared and interpreted gravity and aeromagnetic maps covering an area within and adjacent to the study region. Such data provide information on the subsurface distribution of rock masses and the structural framework.

Geology

The bedrock of the study region is composed of Tertiary volcanic rocks. Rhyolite and basalt volcanism in the area began about 14 million years ago with the eruption of five sequences of rhyolitic ash-flow tuffs from the Juniper Mountain volcanic center (Ekren and others, 1984). At least two of these five units are exposed within the study region. The rhyolites are overlain by a thick sequence of basalt flows, which forms the flat cap of the upper plateau.

Stratigraphy

The oldest unit exposed in the study region is the Swisher Mountain Tuff, the second cycle of tuffs erupted from the Juniper Mountain center. The base of the unit is not exposed, but the Swisher Mountain Tuff is at least 620 ft thick as indicated by exposures in cliffs at the northern end of the wilderness study areas.

Like many rhyolites, the Swisher Mountain Tuff exhibits characteristics of both lava flows and pyroclastic flows (detrital volcanic rocks that have been explosively or aerially ejected from a volcanic vent). It is composed of a thick, homogeneous, flow-banded porphyritic rhyolite throughout the study region. However, pyroclastic textures visible microscopically demonstrate its ash-flow tuff origin. Ekren and others (1984) hypothesize that the Swisher Mountain Tuff was erupted at unusually high temperatures, causing the hot ash to coalesce to a liquid state upon deposition, and flowed at the base. Continuous vertical cooling joints and the lack of correlative horizons of vitrophyre or breccia suggest that the Swisher Mountain Tuff formed a single cooling unit in the study region.

Minor associated rhyolitic volcanism may have been centered within the wilderness study areas. A dome-shaped plug on the west side of the inner canyon, just south of Bull Camp, is cored by frothy glass having vertical flow foliation that grades outwards laterally through vitrophyre to convoluted, flow-banded rhyolite (loc. MLN 119, pl. 1). Near the southern tip of the study region, an orange felsic dike intrudes black vitrophyre of the Swisher Mountain Tuff (loc. MLS 103). However, no evidence of alteration or hydrothermal activity is present at either locality.

The Swisher Mountain Tuff is conformably overlain by rhyolitic rocks composing the lobes of the Juniper

Mountain volcanic center. Ekren and others (1984) distinguish lower and upper lobes near Juniper Mountain. Exposures in the three wilderness study areas do not allow for these units to be separated; the lone exposure is mapped as lobes of Juniper Mountain undifferentiated.

A sequence of vitrophyres and tuff breccias crops out below a reservoir just northeast of Coyote Hole (loc. EFN O24) and marks the basal contact of the lower lobes of the tuff of Juniper Mountain. Like the Swisher Mountain Tuff, it is a densely welded ash-flow tuff, which likely fused before final emplacement (Ekren and others, 1984). It is as much as 220 ft thick in the study region.

Widespread dense rhyolitic tuffs of both units show characteristics of both lava flows and pyroclastics. Ekren and others (1984) believe that this is due to exceptionally high eruptive temperatures, which caused rocks initially erupted as ash flows to coalesce to a liquid state before final emplacement and cooling. Red, densely welded tuffs of the lobes of Juniper Mountain (Ekren and others, 1984) and Swisher Mountain Tuff are similar megascopically and difficult to distinguish in their weathered state in the field. However, the two are easily separated petrographically.

Rhyolitic tuffaceous sandstones and lacustrine tuffs define the unconformable nature of the contact between the Swisher Mountain Tuff and the overlying basalt of Devil's Corral. A hiatus of about 4 million years between the two types of volcanic activity resulted in the erosion of the rhyolitic cap and redeposition of the tuffaceous material in paleotopographic lows. These tuffaceous sedimentary rocks mark the base of the basalt of Devil's Corral. The oldest basalts (10 million years old) interfinger with the sedimentary rocks, showing partial contemporaneity.

The basalt of Devil's Corral was mapped previously as Banbury Basalt. The Banbury Basalt was originally named by Stearns (1936, p. 435) and formalized by Malde and Powers (1962, p. 1204) for exposures of basalt and tuffaceous sediment overlying Idavada Volcanics near Banbury Hot Springs on the Snake River, Idaho. Basalt at the type section of the Banbury has been radiometrically dated at 4.4–4.9 Ma (Armstrong and others, 1975) and is chemically distinct from basalts of the Owyhee Upland (Hart and others, 1984). Basalts in the study region (10–6 Ma) are not time-correlative to the Banbury Basalt and are different chemically. The informal name, the "basalt of Devil's Corral," is hence used in this report and on the accompanying geologic map. It is named for exposures at Devil's Corral in the southern South Fork Owyhee River Wilderness Study Area, where cattlemen erected a fence between convergent basalt cliffs to form a natural corral.

The basalt of Devil's Corral is made up of many thin flows (generally less than 30 ft thick). Cooling joints extending across some flow contacts indicate that little time elapsed between such flows. Paleosols (ancient soils) present between other flows represent greater time gaps. Total thickness of the unit is approximately 775 ft.

Landslide deposits, characterized by hummocky topography, are especially abundant in the area of the canyon on the Nevada-Idaho boundary.

Petrography and Geochemistry

Both the Swisher Mountain Tuff and the lower lobes of the tuff of Juniper Mountain show pyroclastic characteristics in thin section. The matrix of both units contains fused and flattened glass shards in various stages of devitrification. Strongly embayed and resorbed phenocrysts of feldspar and quartz indicate superheating of melts that erupted initially as ash.

The Swisher Mountain Tuff is distinct petrographically and chemically from the lobes of the tuff of Juniper Mountain. Densely welded ash-flow tuffs of the Swisher Mountain Tuff contain an average of 20 percent phenocrysts, of which about 45 percent are plagioclase and 35 percent potassium feldspar. Equal proportions of clinopyroxene and opaque oxides make up the remaining 20 percent phenocrysts; quartz is rare. SiO_2 averages 72 weight percent. The Swisher Mountain Tuff is low in calcium and magnesium and relatively high in total iron.

Conversely, the lower lobes of the tuff of Juniper Mountain are rich in quartz. Phenocrysts average 30 percent of the rock, of which 30–70 percent are quartz. Potassium feldspar makes up 25–65 percent of the phenocrysts. Small amounts of plagioclase (5 percent) may be present and a few percent each of clinopyroxene and opaque oxides. The lower lobes of the tuff of Juniper Mountain are higher in SiO_2 (79 weight percent) than is the Swisher Mountain Tuff and are relatively depleted in calcium, magnesium, and total iron. The lower lobes of the tuff of Juniper Mountain possibly represent a more evolved differentiate of the same magma reservoir that generated the Swisher Mountain Tuff.

Minor amounts of green celadonite were identified from the lacustrine tuffs and tuffaceous sandstones at the unconformable contact between rhyolite and basalt.

The basalt of Devil's Corral is uniform texturally and mineralogically. The rocks are holocrystalline (no glass), subophitic (a type of intergrowth of euhedral plagioclase and pyroxene), and commonly contain intergrown clusters of olivine. Plagioclase laths constitute as much as 50 percent of the rock. Anhedral crystals of clinopyroxene (augite) and intragranular iddingsitized olivine constitute 20 percent each. Opaque oxides (10 percent) are also present. Secondary amygdaloidal calcite and microscopic zeolite-group minerals fill vesicles in some basalts. Chemically, the basalt averages 47 percent SiO_2 and is characterized by low potassium and intermediate titanium. The basalt is a "transitional tholeiite" under Hart and others' (1984) classification, intermediate in composition between typical Snake River Plain and Great Basin basalts.

Geochemistry

Introduction and Analytical Methods

Geochemical sampling of the Owyhee Canyon and South Fork Owyhee River Wilderness Study Areas was accomplished by collecting a total of 84 heavy-mineral concentrates from stream-sediment samples from the South Fork of the Owyhee River and several of its tributaries, from Fourmile Creek to the 45 Ranch (pl. 1). Fifty-one nonmagnetic and 19 intermediately magnetic heavy-mineral concentrates were obtained from 59 stream-sediment collecting sites within the northern South Fork Owyhee River Wilderness Study Area, and 9 nonmagnetic heavy-mineral concentrates were collected from the other study areas by H.D. King, Harlan Barton, and other USGS personnel; 5 similar samples were collected by D.S. Hovorka and M.J. Luessen from the study region. Additionally, 59 stream-sediment samples sieved to minus 0.18 mm (millimeters) and 47 whole-rock samples from outcrops were collected. Access to the sites was by raft during a period of high runoff in May 1984, helicopter and ground collection in 1985, and raft and ground collection in June–July 1985. David L. Bowling, Matthew L. Paige, Kimberly R. Greene, and Thomas H. Greenhalgh assisted in sample collection during the 1984 field season.

Stream-sediment samples represent the chemistry of the rock material upstream from each sample site and are useful in identifying basins containing concentrations of elements that may be related to mineral deposits. Nonmagnetic heavy-mineral concentration isolates many ore-related minerals and permits determination of some elements that are not easily detected in stream-sediment samples. Intermediately magnetic heavy-mineral concentrates contain limonite and manganese oxides, which may contain high concentrations of trace metals indicative of mineral deposits. Analysis of bulk rock samples helps in establishing background values for various elements. Analytical data and a description of the sampling and analytical techniques used are given in Erickson and others (1986) and Day and Barton (1986).

Rock samples were crushed and pulverized to less-than-0.18-mm grain size prior to analysis. Stream-sediment samples were sieved in 80-mesh (0.18 mm) stainless-steel sieves, and the less-than-0.18-mm fraction was used for analysis. Bromoform (specific gravity 2.86) was used to remove light mineral grains from the pan-concentrated stream sediments. By use of an electromagnet, the resultant heavy-mineral concentrate was separated into three fractions: a magnetic fraction, chiefly magnetite; an intermediately magnetic fraction consisting largely of mafic rock-forming minerals; and a nonmagnetic fraction composed dominantly of light-colored rock-forming accessory minerals and primary and secondary ore minerals. The nonmagnetic fraction was split into two fractions with a microsplitter. One of these splits was used for analysis and the other for visual examination with a binocular microscope.

All samples were analyzed semiquantitatively by direct-current arc-emission spectrographic methods, rock and stream-sediment samples by the method described by Myers and others (1961), and nonmagnetic and intermediately magnetic heavy-mineral concentrates for 31 elements by the Grimes and Marranzino (1968) method. Certain elements of special interest or those having lower limits of determination by emission spectrography (including antimony, arsenic, bismuth, cadmium, and zinc) were analyzed in rock and stream-sediment samples by an inductively coupled argon plasma-atomic emission spectroscopy method (after Crock and others, 1983), incorporating a modification of the O'Leary and Viets (1986) digestion method. A portion of the stream sediments was analyzed for mercury by a modified Koirtyohann and Khalil (1976) cold-vapor atomic-absorption method.

Results

No anomalous element concentration values were determined for samples from the Nevada wilderness study areas (NV–010–106 and NV–010–103A) except for sediment samples OH002 (pl. 1), which contained 500 ppm lead in the nonmagnetic heavy-mineral concentrate. Values for other associated elements in samples from this site were calcium, 50 percent, and barium, greater than 10,000 ppm. Concentrations of elements in mafic rock-forming minerals in this sample were low: iron, 0.2 percent; magnesium, 0.1 percent; and titanium, 0.2 percent. Site OH002 is on the South Fork of the Owyhee River approximately 2.9 mi downstream (northwest) of the confluence with Fourmile Creek. Fourmile Creek is a minor south-flowing stream containing a spring that enters the river near a corral and cabin ruins. The upper part of the stream is crossed by jeep trail. This single anomalous lead value may be due to contamination, as this is the only site near observable man-made works, for example, corral, cabins, and jeep trail. The contaminant could be in the form of scrapings from shotgun pellets, rifle or pistol bullets, automotive battery plates or solutions, paint chips, or other man-made substances whose physical or chemical weathering products contain lead.

This single occurrence of lead associated with high calcium content but not with anomalous amounts of other elements (for example, copper, zinc) generally associated with base-metal mineralization may indicate the presence of mineralized calcite and barite veins in the Tertiary volcanic rocks. Zinc was not detected but has a relatively high detection limit (500 ppm) by the emission spectrographic method, so its lack of detection is not unexpected. The association of high calcium and barium values argues for mineralization rather than contamination, but several other samples have equally high calcium and barium and are not associated with anomalous concentrations of lead. Base-metal (copper, lead, zinc) mineralization in the Tertiary volcanic rocks of the area would be contrary to the generalization of Granger and others (1957), who characterize the Tertiary volcanic rocks of Elko County as having yielded principally precious metals (gold and silver) and the pre-Tertiary rocks as yielding principally base metals.

Anomalous concentrations of tin, barium, molybdenum, and copper were detected in sediment samples from the Idaho part of the South Fork Owyhee River Wilderness Study Area (ID–016–053).

Four nonmagnetic heavy-mineral-concentrate samples (SF205T3, S0011AC, SOR009C3, SOR013H3, pl. 1) contained anomalous concentrations of tin (greater than 1,000 ppm). The tin mineral cassiterite (variety wood tin) was identified in the split of sample SOR013H3 by microscopic examination. The anomalous tin concentrations in the other samples are probably also due to the presence of the same mineral. The source of the cassiterite is unknown. Rhyolites and basalts of this area are not known to contain cassiterite. Rhyolite-hosted tin deposits are unknown in the region but do occur elsewhere in the Western United States.

An anomalous concentration of 15 ppm tin was detected in a stream-sediment sample (SF005DS) collected in the northern part of the study area. No other elements in anomalous concentration were detected in this or other samples from this site.

Five nonmagnetic concentrates from stream sediments (SF009D3, SO008AC, SOR001C3, SOR003C3, and SOR004C3) contained high concentrations of barium (10,000 to greater than 10,000 ppm), due to the presence of the barium sulfate mineral barite, which was identified in the mineralogic splits of these samples.

Anomalous values of molybdenum were reported for samples from a tributary to the South Fork of the Owyhee River at the northern end of the study area. An intermediately magnetic heavy-mineral concentrate (SOR020C2) contained 50 ppm molybdenum and a nonmagnetic concentrate (SF004C3) contained 200 ppm. The high value of 200 ppm may be due to the presence of a molybdenum mineral, such as molybdenite; however, no molybdenum mineral was noted in the split used for microscopic examination. The molybdenum in the intermediately magnetic fraction may occur in iron or manganese oxides that have become enriched in molybdenum by adsorption. A type of molybdenum deposit that might be considered is known in Mexico and consists of molybdenite occurring as disseminations in rhyolite flows, tuffs, and other rock types (Boyle, 1974, p. 33). Geological and geochemical information for these wilderness study areas, however, provides little support for this type of molybdenum deposit in the study areas.

An anomalous value for copper (200 ppm) was obtained for a nonmagnetic heavy-mineral concentrate collected at the northern border of the Idaho study area (SF002DC3). The basin upstream from the sample site is entirely outside the wilderness study area.

Geophysics

Gravity and aeromagnetic data were interpreted for the Owyhee Canyon and South Fork Owyhee River Wilderness Study Areas. The gravity data were compiled from the U.S. Department of Defense data bank (National Oceanic and Atmospheric Administration National Geophysical Data Center), from Bankey and others (1985), and from Erwin and others (1985). The aeromagnetic data were obtained from Geo-Life, Inc. (1979) (flown with 3-mi spacing and at 400 ft above ground), from the U.S. Geological Survey (1972) (flown with 2-mi spacing and at 9,000 ft above sea level), and from the U.S. Geological Survey (1971) (flown with 5-mi spacing and at 12,500 ft above sea level).

The gravity and aeromagnetic data define only regional features due to the lack of detailed data coverage. Two major crustal features are expressed in both the gravity and aeromagnetic data across the wilderness study areas. Both features probably exist within the basement but still may help define the regional controls for mineral resource potential evaluations.

Gravity Data

The complete Bouguer gravity anomaly map (fig. 3) generally represents deviations in rock density from 2.67 g/cm^3 (grams per cubic centimeter). Data coverage is insufficient for detailed analysis in the wilderness study areas, but is useful in determining regional features.

The South Fork region of the Owyhee River is on a regional gravity high (A, fig. 3) that gradually grades into a steep-sided gravity low (B, fig. 3) centered just outside the Owyhee Canyon area. This gravity high probably represents crystalline basement rocks at a shallower depth than elsewhere in the region. The geological map of Ekren and others (1984) shows a fault-bounded horst corresponding to the central part of the high. The low (B) extends 15 km to the east and is bounded on the west by a small gravity high whose shape is not well constrained by the data. The low generally corresponds to a mapped exposure of Circle Creek Rhyolite to the northeast of the Owyhee Canyon Wilderness Study Area that is interpreted to be a lekolith (bowl- or basin-shaped extrusive complex) (Coats, 1968). The gravity data may

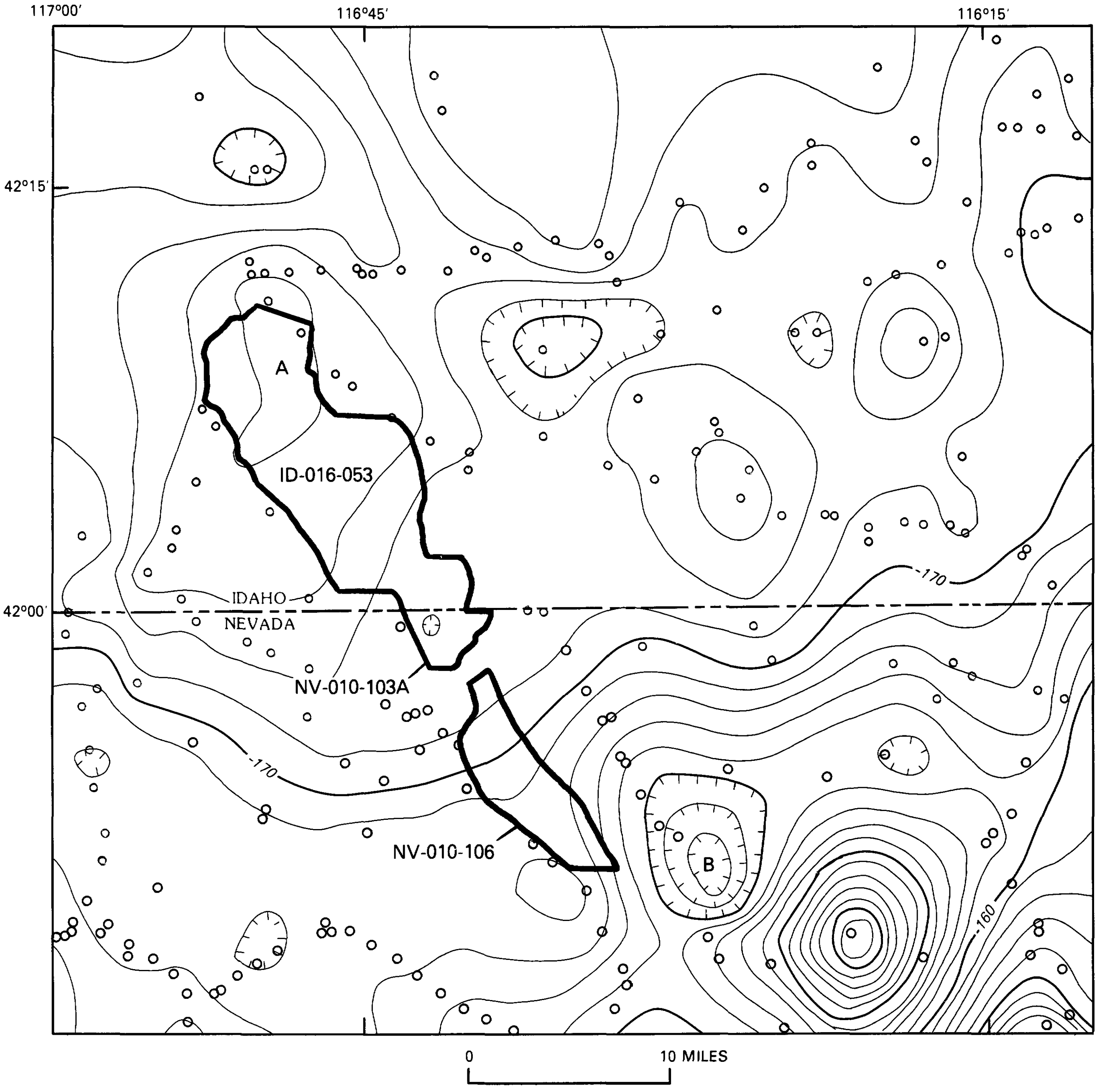

Figure 3. Regional complete Bouguer gravity anomaly map of the Owyhee Canyon and South Fork Owyhee River Wilderness Study Areas and vicinity. Data were retrieved from many sources (listed in text). Reduction density of 2.67 grams per cubic centimeter used for Bouguer and terrain corrections. Gravity-station locations are indicated by circles. A, gravity high; B, gravity low. Contour interval 2 milligals; hachured lines indicate area of closed gravity low.

substantiate the interpretation and suggest that the deepest part of the lekolithic structure (the lowest part of the gravity low) is offset from the exposure at the surface.

The gradient between the high at A and low at B is part of a major gradient trend that cuts through the northern section of the Owyhee Canyon Wilderness Study Area, extending 35 mi to the west and 25 mi to the east-northeast. Correspondence of this gradient with a major aeromagnetic high (B on fig. 4) suggests the presence of a major boundary between different rock types at depth. The edge of the lekolith or an associated structure may be related to the boundary.

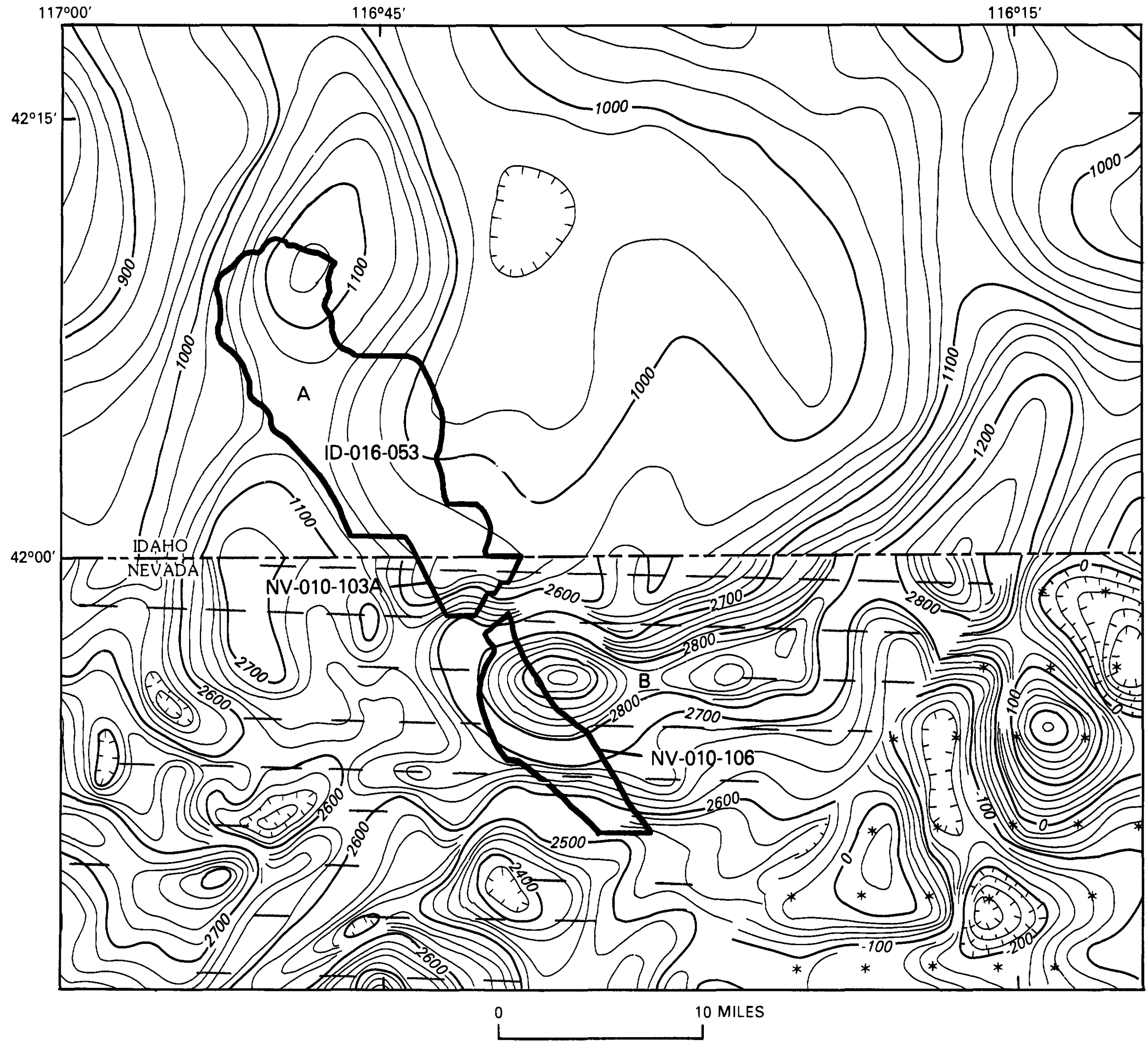

Figure 4. Regional aeromagnetic map of the Owyhee Canyon and South Fork Owyhee River Wilderness Study Areas and vicinity. Data are from three different surveys whose boundaries are evident by the break in contouring. The northern survey (U.S. Geological Survey, 1971) was flown at 5-mi line spacings, 12,500 ft above sea level; flight lines are not shown on the figure. The southwestern survey (U.S. Geological Survey, 1972) was flown at 2-mi line spacings, 9,000 ft above sea level; flight lines are shown as long-dashed lines. The southeastern survey (Geo-Life, Inc., 1979) was flown at 3-mi line spacings, 400 ft above ground; flight lines are indicated by asterisks. A and B are aeromagnetic highs. Contour interval 20 gammas; hachured lines indicate area of closed magnetic low.

Aeromagnetic Data

The residual aeromagnetic anomaly map (fig. 4) generally represents changes in the magnetic field caused by differences in the magnetic properties of rocks. Data coverage is useful in determining regional features only.

The area of the South Fork of the Owyhee River is crossed by a major north-south-elongated magnetic high (A). It generally corresponds to the gravity high A (fig. 3) and, as discussed above, suggests the presence of crystalline basement at a shallower depth.

Aeromagnetic high B is associated with a regional gravity gradient trend and extends 6 mi to the east from the Owyhee Canyon area, then veers to the northeast another 12.5 mi. This high may represent a structural or lithologic feature that is associated with a lekolith, discussed above. Preliminary depth estimates indicate a minimum depth to the top of the feature as 1.1 mi below the surface.

Mineral and Energy Resource Potential

Metal Deposits in Tertiary Volcanic Rocks

Tertiary olivine basalt flows partially cover an older Tertiary rhyolite terrane within the three wilderness study areas. On the basis of geologic mapping, geochemical and geophysical studies, and lack of mining-related activities, we conclude that all of the volcanic rocks are unlikely to host metal deposits. No areas of hydrothermally altered rocks or evidence of hydrothermal vein structures were found. The extremely minor amounts of cassiterite found in 4 of 51 nonmagnetic stream-sediment samples collected in the northern part of the study region (ID–016–053) are likely derived from the rhyolitic units. The three wilderness study areas have low mineral resource potential for all metals, with a certainty level of C.

Energy Resources

The three wilderness study areas also lack host rocks and structures favorable for the occurrence of oil and gas or coal. Depth to potential source or reservoir rocks is unknown. Sandberg (1983a, b) has rated the petroleum resource potential for the three areas as zero or low. Oil and gas leases and lease applications cover large parts of the study region, but no resources have been identified. Energy potential for oil, gas, and coal resources is rated as low, with a certainty level of C.

Geothermal Resources

No thermal waters are known within the wilderness study areas, and the potential for geothermal resources in the areas is therefore considered low, with a certainty level of C.

Industrial Rocks and Minerals

Sand and gravel deposits are present in the wilderness study areas, and volcanic rocks that might be used as dimension stone or decorative rock are widespread. They are treated as identified resources and are discussed in that preceding section of this report. No significant occurrences of zeolites or diatomite were found in the study region. There are small occurrences of opal and (or) chalcedony in the northern part of the South Fork Owyhee River Wilderness Study Area, but the quality and desirability are low. The mineral resource potential for industrial minerals and rocks is thus rated as low, with a certainty level of C.

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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.

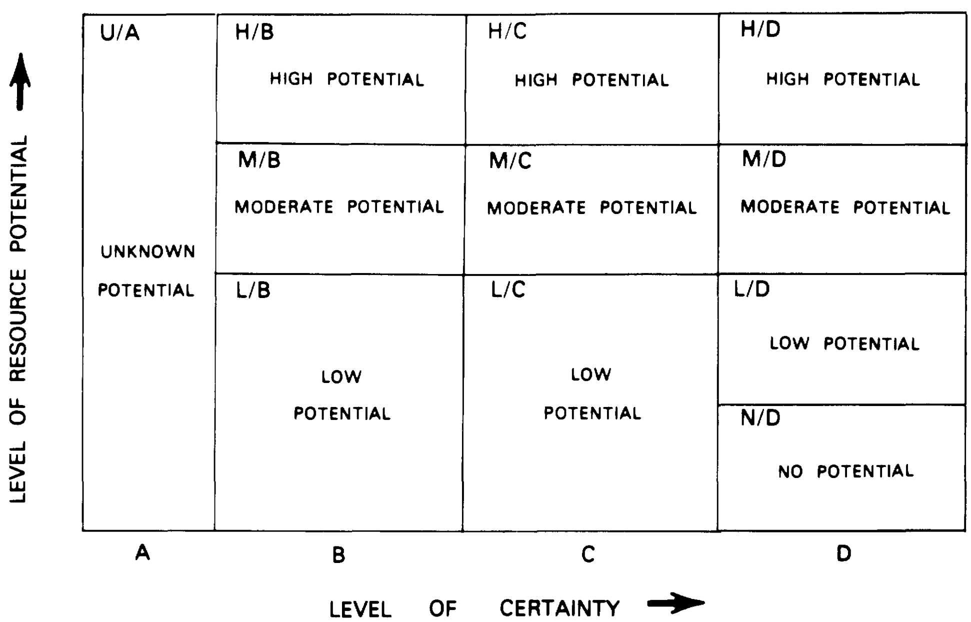
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application 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



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.

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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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