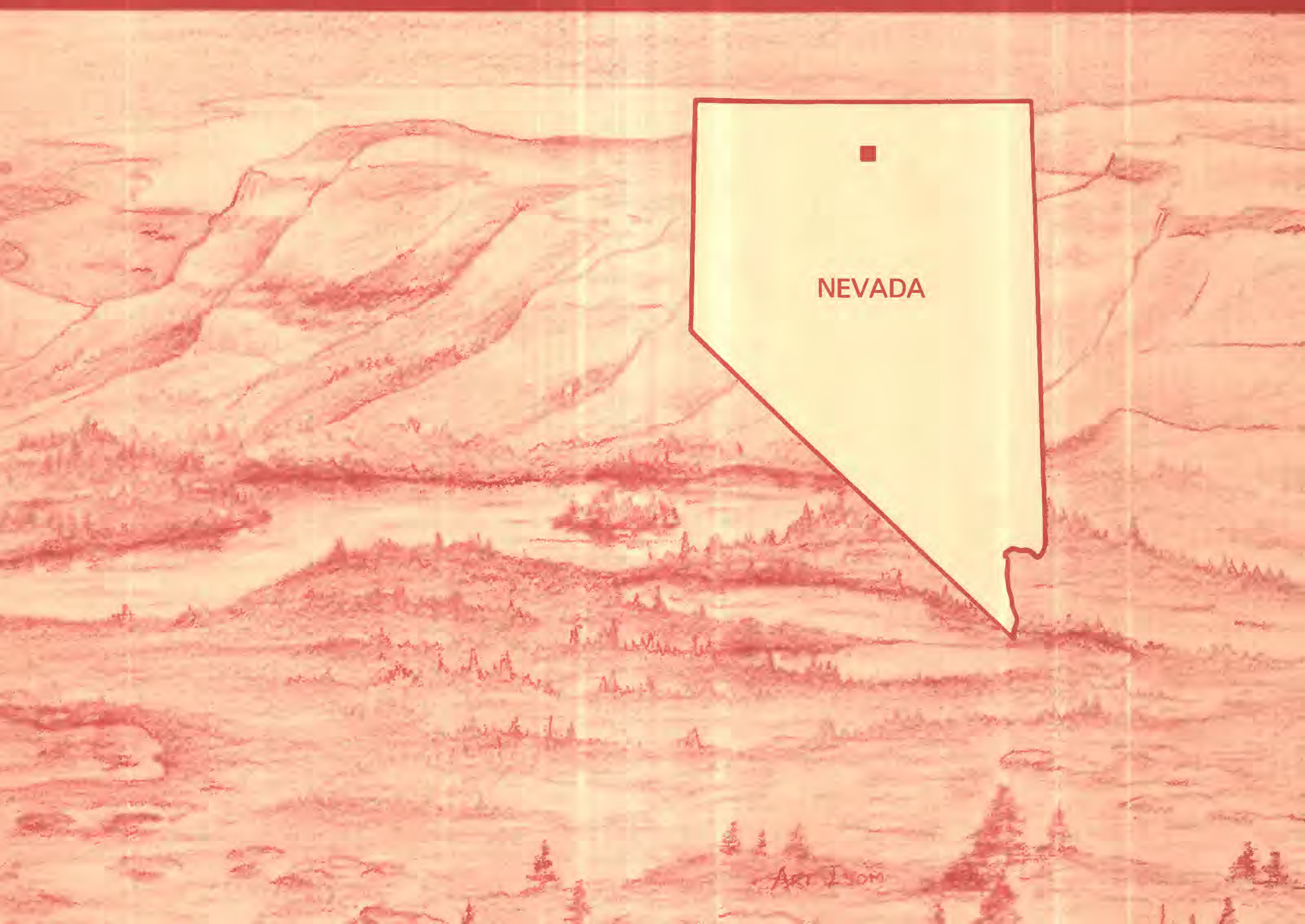
Mineral Resources of the Little Humboldt River Wilderness Study Area, Elko County, Nevada

U.S. GEOLOGICAL SURVEY BULLETIN 1732–B



Chapter B

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U.S. GEOLOGICAL SURVEY BULLETIN 1732

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
LITTLE HUMBOLDT RIVER REGION, NEVADA

DEPARTMENT OF THE INTERIOR
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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 a part of the Little Humboldt River Wilderness Study Area (NV–010–132), Elko County, Nevada.

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PLATE

[Plate is in pocket]

FIGURES

Mineral Resources of the Little Humboldt River Wilderness Study Area, Elko County, Nevada

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SUMMARY

Abstract

The Little Humboldt River Wilderness Study Area (NV–010–132) in northern Nevada is underlain by faulted volcanic rocks. The study area has no identified mineral resources (fig. 1). Numerous mining companies are actively exploring for gold in and around the wilderness study area. Different parts of the area have a high, medium, or low mineral resource potential for disseminated gold deposits and zeolites. Some areas have an unknown mineral resource potential for bedded barite and disseminated gold in rocks beneath the volcanic cover. The entire study area has a low resource potential for uranium and thorium, diatomite, tin, arsenic, antimony, silver, and mercury, oil and gas, geothermal energy, and sand and gravel.

Character and Setting

The Little Humboldt River Wilderness Study Area includes 40,000 acres (66 square miles) in western Elko County, northern Nevada (fig. 2). It occupies a broad, sage-covered upland basin surrounded on the west, south, and east by ridges. The study area can be reached by good to very poor dirt roads from the south, west, and north. Elevations range from 5,079 ft (feet) to 7,266 ft, and the South Fork of the Little Humboldt River has incised a narrow canyon that longitudinally bisects the wilderness study area.

The study area is between the predominantly volcanic Snake River Plain volcanic province to the north and the structurally complex Basin and Range province to the south. Faulted and deformed older sedimentary and igneous rocks in the Basin and Range province are exposed in north-trending mountains that are separated by broad valleys filled with alluvium. In the transition zone between the two terranes, the volcanic rocks partly to completely cover the older rocks.

The wilderness study area is underlain by a complex, interlayered sequence of volcanic rocks that were erupted between about 10 and 15 m.y. (million years) ago. The oldest rocks are rhyolitic flows and tuffs and lesser amounts of ash-rich sedimentary rocks and andesitic flows, dikes, and tuffs. These rocks were cut by steep faults that produced a large, north-trending basin. Ash-flow tuffs were erupted into this basin as it developed, forming the widespread tuff of the Little Humboldt River. Subsequently, widespread shallow lakes covered surrounding areas, and large volumes of crystal-rich rhyolitic flows were erupted just west of the wilderness study area. About 10 m.y. ago, basalt flows were erupted near the northeastern edge of the study area. Active faulting during volcanic activity produced a complex relation between volcanic units and various fault systems.

Resources

Different parts of the study area have a high, medium, or low resource potential for disseminated gold deposits and for zeolites in tuffaceous sedimentary rocks (fig. 1). The study area does not have any identified mineral resources.

Altered and fractured rocks, numerous quartz veinlets, and geochemical anomalies indicate that some of the older volcanic rocks at the southeast end of the study area near Brush Creek and along the western margin near Snowstorm Creek have a high resource potential for disseminated gold deposits. An area along the South Fork of the Little Humboldt River was hydrothermally mineralized and has a

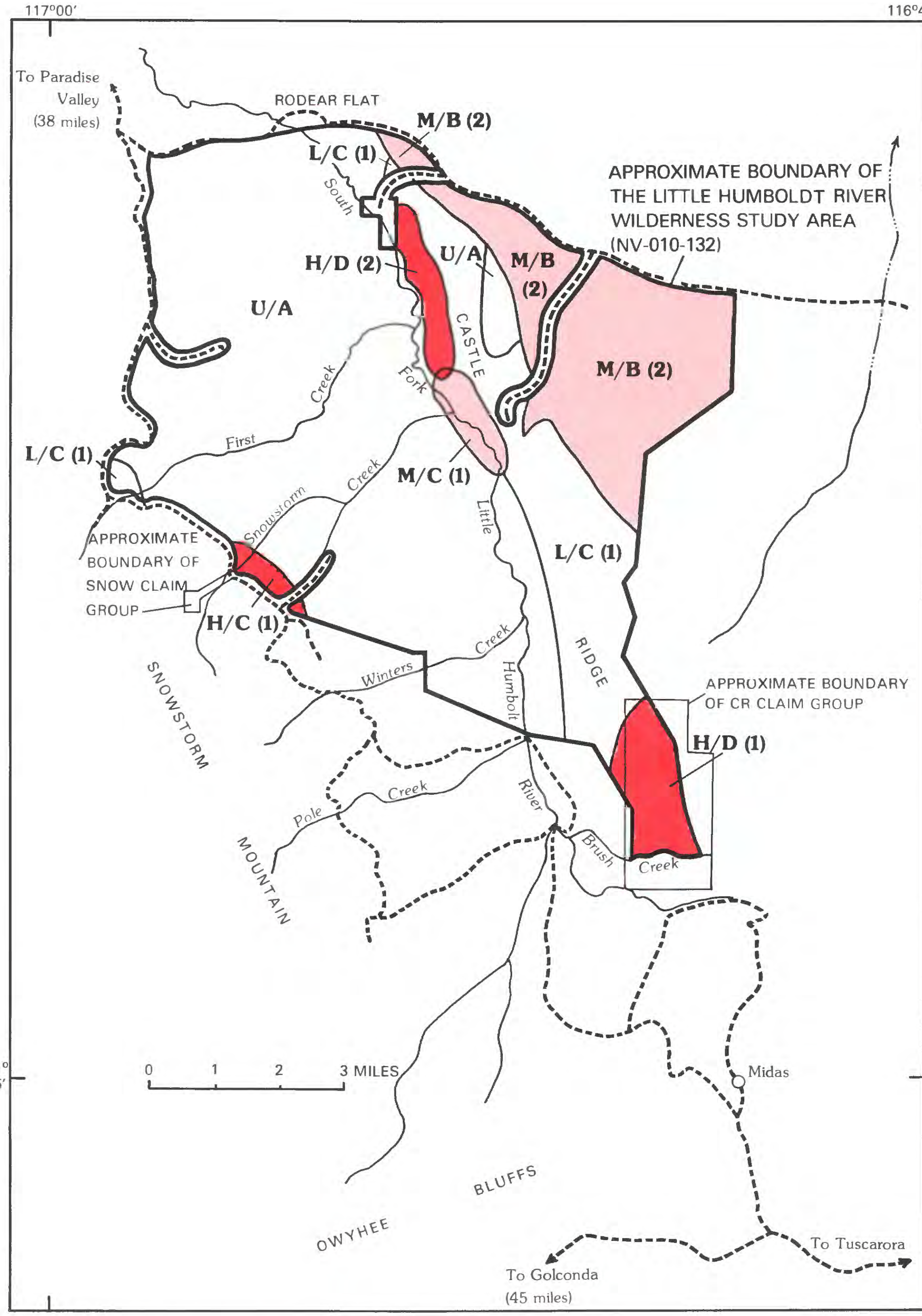


Figure 1 (above and facing page). Summary map showing mineral resource potential of the Little Humboldt River Wilderness Study Area, Elko County, Nev.

EXPLANATION

[Except for parts of study area designated below as having high or moderate potential for commodity 2, the study area has a low mineral resource potential for commodity 2 (certainty level D). Entire study area has a low mineral resource potential for tin, uranium and thorium, sand and gravel and oil and gas (certainty level D) and for arsenic, antimony, mercury, silver, geothermal energy, and diatomite (certainty level C)]

H/C,D Geologic terrane having a high mineral resource potential for commodity 1 (certainty level C or D) or for commodity 2 (certainty level D)—Commodity shown on figure by number in parentheses

M/B,C Geologic terrane having a moderate mineral resource potential for commodity 1 (certainty level C) or for commodity 2 (certainty level B)—Commodity shown on figure by number in parentheses

L/C Geologic terrane having a low mineral resource potential for commodity 1 (certainty level C)—Commodity shown on figure by number in parentheses

U/A Geologic terrane having an unknown mineral resource potential for commodity 1 (applies to all parts of study area not designated as having high, moderate, or low potential for commodity 1) and (or) for commodity 3 (applies to entire study area)

Commodities:

1. Disseminated gold
2. Zeolites
3. Barite

Levels of certainty

- A Available data not adequate to determine resource potential
- B Data indicate geologic environment and suggest level of resource potential
- C Data indicate geologic environment, give good indication of level of resource potential, but do not establish activity of resource-forming processes
- D Data clearly define geologic environment and level of resource potential

moderate resource potential for a disseminated gold deposit. Underlying pre-volcanic sedimentary rocks may also contain disseminated gold deposits, but the level of this potential is unknown. The remainder of the study area has a low potential for volcanic-hosted disseminated gold deposits.

Chemical changes during the conversion of ash-rich sediments into rocks result in the formation of zeolites. Tuffaceous sedimentary rocks in the northeastern part of the study area have a high or moderate resource potential for zeolites. The remainder of the study area has a low potential for zeolites.

The study area has a low resource potential for uranium and thorium, oil and gas, diatomite, tin, arsenic, silver, mercury, and antimony, geothermal energy, and sand and gravel. The underlying pre-volcanic sedimentary rocks have an unknown resource potential for bedded sedimentary barite deposits as well as carbonate-hosted disseminated gold deposits.

INTRODUCTION

That portion of the Little Humboldt River Wilderness Study Area (NV–010–132) evaluated for mineral resources and mineral resource potential, hereafter referred to as the "wilderness study area"or simply the "study area," covers 40,000 acres in western Elko County, Nev. It is 50 mi (miles) northeast of Winnemucca, 50 mi north of Battle Mountain, and 5 mi north of the small hamlet of Midas. Good to extremely poor dirt roads provide access to the north, west, and south sides; these roads connect with graded county roads that lead west to Paradise Valley and south to Interstate Highway 80. Several dirt roads penetrate the study area, providing some access to the interior. Cattle and wild horse trails are the most expeditious routes through the locally dense sagebrush.

The study area is near the headwaters of the South Fork of the Little Humboldt River. It is situated in a gently north-sloping upland basin that is surrounded on the west, south, and east by ridges with small groves of aspen. Elevations range from 5,079 ft at the north end of the study area to 7,266 ft near the south end; the surrounding ridges are as high as 8,400 ft. The river has incised a 600-ft-deep canyon that longitudinally bisects the study area. Aspens, cottonwoods, willows, alders, and wild rose bushes line small perennial streams, but much of the area is covered only by various species of sage, rabbitbrush, and grasses. More than 79 species of birds were observed during the two field seasons, and brilliantly colored carpets of wildflowers blanket the area in the late spring and early summer. The South Fork of the Little Humboldt River is host to the Lahontan strain of cutthroat trout as well as numerous crayfish.

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 (USBM) and U.S. Geological Survey (USGS). Identified resources are classified according to the system of the USBM and USGS (1980), which is shown in the appendix of this report. Identified resources are studied by the USBM. Mineral resource potential, which is the likelihood of occurrence of undiscovered metals and nonmetals, industrial rocks and minerals, and of undiscovered energy sources (coal, oil, gas, oil shale, and

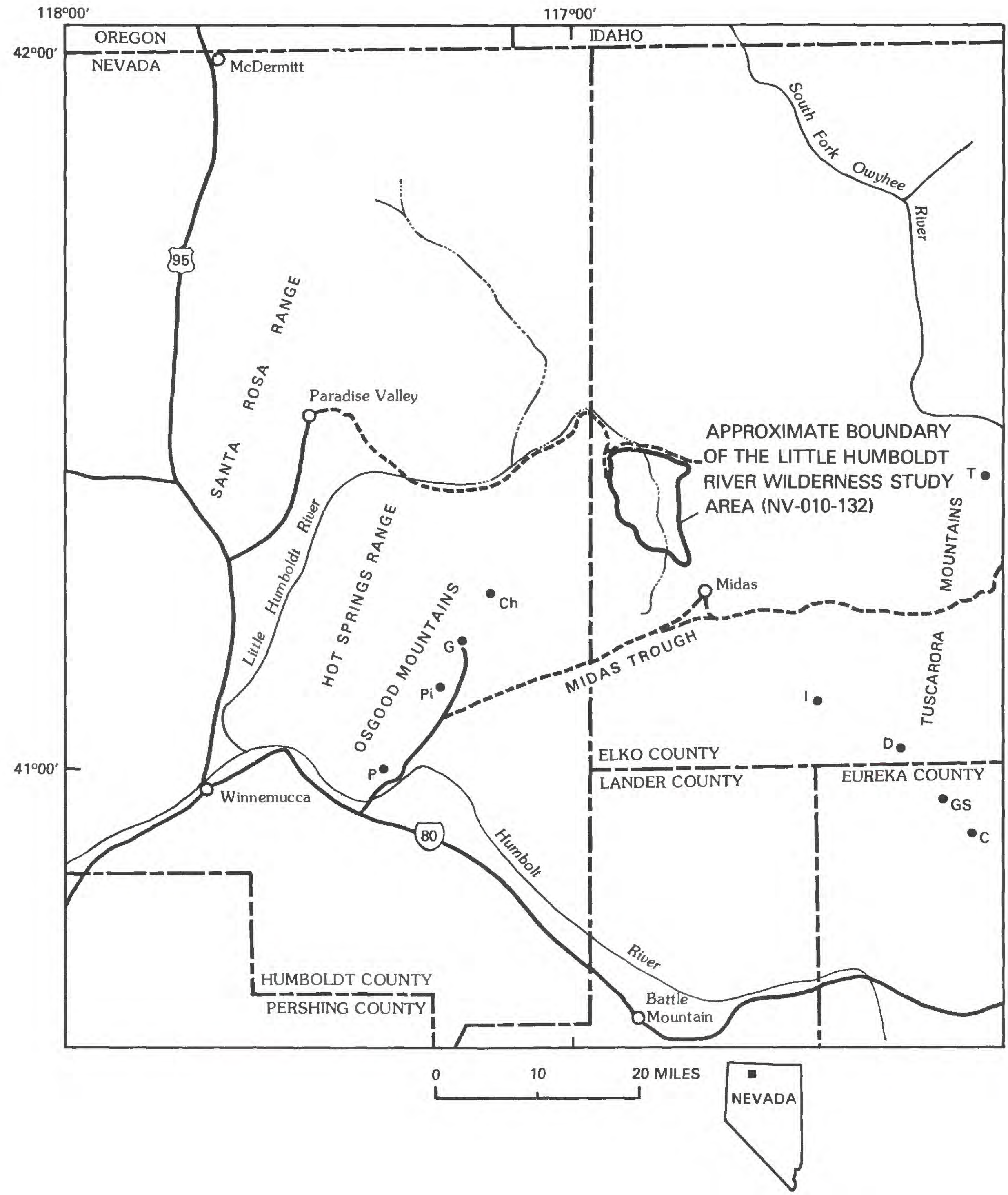


Figure 2. Index map showing the location of the Little Humboldt River Wilderness Study Area in western Elko County, Nev. Shown also are selected active gold mines or historic gold districts in the region: Getchell trend–Preble (P), Pinson (Pi), Getchell (G), Chimney (Ch), Carlin trend–Carlin (C), Gold Strike (GS), Dee (D), Ivanhoe district (I), Tuscarora district (T). The towns of McDermitt, Battle Mountain, and Midas (Gold Circle district) are also historic and modern centers of mining activity.

geothermal sources), is classified according to the system of Goudarzi (1984), shown in the appendix of this report. Undiscovered resources are studied by the USGS.

Investigations by the U.S. Bureau of Mines

Work by the USBM entailed pre-field, field, and report preparation phases in 1985–1986. Pre-field studies included library research and perusal of Elko County and BLM mining and mineral lease records. USBM, state, and other production records were searched, and pertinent data were compiled. Field studies involved searches for all prospects and claims indicated by pre-field studies to be within or near the study area. Those found were examined and, where warranted, were mapped and sampled. Prospects and claims outside, but near, the study area were examined to determine whether mineralized zones might extend into the study area and to establish guides to mineral deposits in the region. In addition, a ground reconnaissance was conducted in each area of obvious rock alteration to check for mining-related activities that may not have been recorded.

Samples collected by the USBM (Gabby, 1987) at mineralized sites include 47 hard-rock, 3 zeolite, 3 diatomaceous earth, 5 placer, and 5 petrographic samples. Hard-rock samples were fire-assayed for gold and silver. At least one sample from each locality was analyzed for 40 elements by semiquantitative methods to detect unsuspected elements of possible significance. Three samples were analyzed by semiquantitative X-ray diffraction for zeolite minerals and were tested for their ammonium cation exchange capacity. Three samples were microscopically examined to estimate diatom and contaminant content. Two were also analyzed for major oxides and loss on ignition. Petrographic examinations were performed to identify selected rock types, alteration suites, and mineral assemblages. Placer samples, partially concentrated in the field, were further concentrated on a laboratory-size Wilfley table. Resulting heavy-mineral fractions were scanned with a binocular microscope to determine heavy-mineral content. Concentrates were also checked for radioactivity and fluorescence. Complete analyses are on file at the USBM Western Field Operations Center, E. 360 Third Ave., Spokane, WA 99202.

Investigations by the U.S. Geological Survey

Geologic mapping and sampling of the study area and evaluation of geophysical data were done by the USGS. Mapping was carried out during three months in the summer of 1985 by A.R. Wallace, M.J. Luessen, and B. Wolde Michael, and for one month in the summer of 1986 by A.R. Wallace. Geologic mapping was done on 1:24,000-scale topographic maps and aerial photographs. Helicopter access was available for one week in 1985; access was otherwise by four-wheel-drive vehicle, motorbike, and foot.

Stream-sediment and heavy-mineral concentrates were collected during the summer of 1985 under the supervision of R.L. Turner. Rock samples were collected by Wallace and coworkers during geologic mapping.

Regional aeromagnetic and gravity data were reduced and evaluated by V.J.S. Grauch and J.L. Plesha. Magnetic measurements were made on six samples, but additional geophysical data were not acquired from the study area. Remote-sensing data were analyzed by M.D. Krohn. Landsat Thematic Mapper data were digitally processed to evaluate the potential for hydrothermally altered rocks within the study area. Regional aerial gamma-ray spectroscopy data were evaluated by J.S. Duval.

Previous geologic studies in the study area were limited to reconnaissance mapping by R.C. Greene of the USGS for the Elko County geologic map (Hope and Coats, 1976). The Gold Circle (Midas) district was described by Rott (1931). Active mineral exploration programs are in progress in and around the study area.

APPRAISAL OF IDENTIFIED RESOURCES

By Peter N. Gabby
U.S. Bureau of Mines

Mining and Prospecting History

The earliest mineral discovery in the vicinity of the study area was of placer gold in the Tuscarora mining district (approximately 30 mi east of the study area) in 1867, followed by the discovery of lode silver-gold in 1871 (Granger and others, 1957, p. 151). There are ten mining districts within 35 mi of the study area: Gold Circle (Midas), which bounds the study area to the south; Burner, Good Hope, Cornucopia, Rock Creek, and Ivanhoe to the east (Granger and others, 1957, pl. 2 and 3); Lynn (Carlin) to the south (Hill, 1912, p. 200, pl. 9); and Potosi, Dutch Flat, and Poverty Rock to the southwest and west (Vanderburg, 1938; Willden, 1964, pl. 3). In addition to gold and silver, these districts have produced copper, lead, zinc, mercury, manganese, and tungsten.

Gold was first discovered in the Gold Circle district in 1907. Six or more mills, ranging in capacity from 25 to 75 tons per day, were operated. The largest operation in the district, the Elko Prince mine and mill, 2.5 mi southeast of the study area, produced about

95,000 oz (troy ounces) of gold and 1.5 million oz of silver. Production from the entire Gold Circle district, from 1908 to 1965, was about 300,000–400,000 tons of ore that yielded about 127,000 oz of gold and 1.6 million oz of silver. None came from the study area.

Because of the current profitability of gold mining and the success of exploration programs in northern Nevada, there presently is a very high level of interest and exploration activity in the vicinity of the study area. Twelve deposits have been located in recent years within 35 mi of the study area: Ivanhoe, Dexter (Tuscarora), Dee, Bootstrap, Carlin, Blue Star, Bullion Monarch, Goldstrike, Genesis, Getchell, Pinson, and Preble. These deposits are at various stages in the life cycle of a mine, from drilling program to producing mine, and they have total resources in the range of 90 million tons containing 10 million oz of gold (Lowe and others, 1985). Seven are currently producing, with a combined total 1985 production of more than 250,000 oz of gold. The active mine nearest to the study area is the Pinson, 22 mi to the southwest. Exploration programs are presently in progress in the Gold Circle mining district and its extension into the study area, in the Scraper Springs area east of the study area, and in the Snowstorm Mountain area along the western border of the study area.

In 1907 and 1908, claims were located as close as 1.5 mi north of Brush Creek and along Snowstorm Creek. A short, caved adit and several prospect pits were found in the area north of Brush Creek. At the beginning of 1985, only part of one current claim was within the study area. A corner of the Snow No. 10 claim, owned by Fred Barnes, overlaps the boundary where Snowstorm Creek enters the study area (fig. 1). While field work was in progress (mid-June 1985) Freeport-McMoRan and Callahan Mining Corporation were locating large areas on the northeast flank of the Snowstorm Mountains with claim groups extending to the study area boundary. In January 1986, a mining company located the CR claim group (fig. 1) composed of 125 contiguous claims in secs. 30 and 31, T. 40 N., R. 46 E., within the study area, and secs. 19, 20, 29, and 32, adjacent to and partly within the study area. The Red claim group, owned by T.R. Iverson, and the JMC claim group, owned by Joshua Mining Company, are adjacent to the CR claim group less than 1 mi from the southern boundary of the study area. ASARCO, Freeport Exploration, Newmont Exploration, and U.S. Steel have been locating claims and conducting exploration 5–9 mi east of the study area.

Two and one-half miles north of the study area, the southern half of T. 42 N., R. 45 E. is leased for oil and gas (Virginia Carmichael, oral commun., 1986). Thirty-six miles northeast of the study area, the Bull Run Oil and Gas Company in 1922 drilled an 800-ft well in the Bull Run Mountains (Lintz, 1957, p. 40–41) and reported the presence of oil and gas; in 1956 Richfield Oil Corporation drilled a 3,386-ft hole nearby, but no shows were reported (Garside and Schilling, 1977).

Mines, Prospects, Claims, and Mineralized Areas

CR Claim Group

The CR claim group covers approximately 4 square miles of the western slope of Castle Ridge, partly in the study area (fig. 1). Access to the southern and eastern sides of the claimed area is by a 3-mi drive north from Midas on jeep trails, followed by a short hike over moderately steep slopes.

The claim group is centered on a cluster of broad ridges, hills, and knobs that buttress Castle Ridge and that are part of a north-northwest-trending, structurally uplifted block. Uplift and erosion have exposed more than 2 square miles of altered volcanic rocks composed predominantly of rhyolite tuffs, flows, domes, flow breccias, and some tuffaceous sediments. Andesitic rocks crop out in the southern part of the claim group. Broad areas of siliceous volcanic rocks, which are oxidized and exhibit weak argillic alteration, and andesitic rocks, which exhibit propylitic alteration, form an irregularly shaped, north-northwest-trending zone averaging 3,000 ft wide. No attempt has been made to map the alteration zone beyond the north perimeter of the claim group into the study area. Commonly superimposed on the large, weakly altered area are zones of sparse to abundant quartz veins, pervasive silicification, and fracture-controlled alunite. There are also several zones of bleached rocks west of the alteration zones. Disseminated pyrite was seen in two areas that contained abundant quartz veins.

A 25-ft-long caved adit and five pits occur on that part of the claim group within the study area. Of the seven samples taken by the USBM, five contained detectable gold, four yielding values from 23 to 45 ppb (parts per billion) and one 218 ppb; two contained 0.52 and 0.74 ppm (parts per million) silver. Preliminary geochemical data supplied by a mining company were interpreted by the USBM to delineate broad areas having anomalous concentrations of gold, mercury, and arsenic. The company's detailed exploration program was conducted after anomalous concentrations of gold were found during a reconnaissance stream-silt survey. One silt sample from Brush Creek contained 8 ppb gold, and another from the drainage basin to the north contained 6 ppb gold. These values are above background amounts for silt derived from the type of rocks present.

Snow Claim Group

The Snow Nos. 1, 2, 3, 8, 9, and 10 claims were located along Snowstorm Creek in 1980 by Fred Barnes of Golconda, Nev. A small part of Snow No. 10 is in the study area (fig. 1). Three prospect pits are on the southern boundary of the claim group.

Evidence of widespread hydrothermal alteration of rhyolitic and andesitic rocks was observed at the prospect pits and for 1.4 mi to the northeast, extending into the study area. The altered and mineralized area contains light-colored, bleached, and silicified volcanic rocks with gray and white quartz veinlets, quartz-cemented breccia, and oxidized, disseminated pyrite. Greenish (possibly propylitically altered), silicified volcanic rocks containing some oxidized, disseminated pyrite were seen along Snowstorm Creek and in the study area. The intensity and type of silicification downstream along Snowstorm Creek grades from abundant to less abundant white quartz veinlets, jasper, and quartz-cemented breccia, and finally to only bands and blebs of chalcedony inside the study area.

Six rock samples were taken from the claim group. The only ore-grade assay, 5.6 ppm gold and 119 ppm silver (0.16 oz/ton gold and 3.5 oz/ton silver), came from a prospect pit 1.2 mi outside the study area. Of the five remaining rock samples, four contained between 21 and 48 ppb gold, and one contained 1.7 ppm silver. Two placer samples from Snowstorm Creek contained trace amounts of scheelite (a tungsten-bearing mineral) but no detectable gold.

JMC and Red Claim Groups

To the south of the study area, a 35-ft-long adit and eight prospect pits on the JMC claim group and the Red claim group were examined to determine if mineralized zones might extend into the study area. The JMC group was located in 1980 and 1981 by Joshua Mining Company of San Francisco, Calif., and the Red group was located in 1979 by T.R. Iverson of Lovelock, Nev. The area examined can be reached by jeep trails 2.5–3 mi north from Midas.

The claimed area is underlain predominantly by andesitic and rhyolitic volcanic rocks and appears to be the southern extension of the broad zone of pervasive propylitic and argillitic alteration found on the CR claim group. Silicified rock, quartz veins, and quartz-cemented breccias are commonly found at the workings. Also, disseminated pyrite was observed in both breccias and silicified material.

Ten samples were taken from the north end of the claim group. Seven samples contained detectable gold, six yielding values from 19 to 25 ppb and one of 359 ppb; three contained between 0.42 and 1.9 ppm silver. No samples had ore-grade values.

Other Metallic Mineral Occurrences

Outcrops of altered and silicified material inside the study area but outside the claimed areas were examined by the USBM, and 24 samples were taken. The four highest gold values are for samples of altered and silicified material from contacts between dark-green andesite and red rhyolite along Castle Ridge. Two of these samples are from a zone that resembles a mineralized breccia sill. The fragments are poorly sorted, angular to subrounded, altered, and cemented by fine-grained quartz (and specular hematite?); the breccia is commonly matrix-supported. Hydrothermal fluids under pressure from mineralized breccia pipes located to the south may have spread laterally along a permeable horizon at the contact between the rhyolite and andesite.

Two level 14-in. panfuls of surficial silt, sand, and gravel were taken at five locations. All five samples contained a trace of scheelite (a tungsten mineral, calcium tungstate). The sample from Oregon Canyon, 1 mi south of the study area, contained subangular gold particles.

Seventy-eight stream-sediment silt samples from inside and adjacent to the study area were collected by a mining company as part of a 261-sample regional study covering about 275 square miles. The study first identified drainage basins showing anomalous concentrations of metals that may be associated with disseminated gold. Detailed follow-up work was then done to locate the bedrock source of the anomalies. Four silt samples from inside the study area contained anomalous concentrations of gold, three contained anomalous concentrations of mercury, and three contained anomalous concentrations of arsenic. Of special interest is a sample containing 20 ppb gold from the drainage basin north of First Creek. This unusually high value (above the 95th percentile) indicates that a near-surface gold deposit may be present to the southwest or west of the sample site.

Diatomite Occurrence

An outcrop of diatomite approximately 20 ft thick is at the northwest end of Rodear Flat, 0.3 mi north of the study area. Diatomite is a light-colored, siliceous, sedimentary rock that consists of microscopic remains of diatoms, one-celled aquatic plants related to algae. Useful characteristics of diatomite, primarily a result of the siliceous diatom skeletons, are a large surface area, high absorptive capacity, and relative chemical stability. Processed diatomite has numerous industrial applications; filter aid uses account for more than half of current consumption (Kadey, 1983, p. 677).

The outcrop at Rodear Flat is the only exposure of diatomaceous material seen; it is a large area of light-colored, fine-grained, powdery material sloughing down a gentle slope on a low-lying ridge. Three samples were taken: two of relatively fresh diatomite from the top of the light-colored zone and one composited over the entire exposure.

Rodear Flat is a small, structurally controlled basin bounded on the north by a fault that may have defined the northern limit of the freshwater lake that produced the diatomite bed. This limits the possible extension of the diatomite to the north to less than 1,000 ft. The lack of other outcrops in the area also suggests the bed thins to the north. The diatomite bed is inferred to be a triangular, tabular body averaging 7 ft thick and estimated to contain 43,000 tons, having a 60- to 85-percent diatom content. Maximum overburden is estimated to be 100 ft. There is no evidence that the diatomite bed extends south to the study area.

Zeolite Occurrences

Zeolite occurrences in the study area were examined at three locations along the Little Humboldt River. Zeolites are hydrated aluminosilicate minerals. Because of the structural features and chemical properties of these minerals, various zeolites having different alumosilicate frameworks can act as ion or molecular sieves, each type having a characteristic use (Deer and others, 1976, p. 393–395). Presently, zeolites are being used for pollution control, water purification, radioactive waste disposal, soil conditioners, animal feed supplements, animal absorbents (cat box filler), deodorizers, catalysts, and drying agents for freon refrigeration equipment (Eyde, 1986, p. 369).

The zeolite-rich outcrops in the study area are light-colored, altered, porous volcanic tuffs having a slight greenish cast, and they are presumed to be stratiform bodies of unknown extent. The samples contained significant concentrations (46–70 percent) of the zeolite mineral clinoptilolite. Material this low-grade would, however, have to be closer to potential markets in order to be classified as an identified resource.

Recommendations for Further Work

Three areas within the study area show anomalous concentrations of gold (one of which is also anomalous in mercury and arsenic), pervasive weak hydrothermal alteration, and some localized brecciation and intense alteration. These three areas are (1) the southern part of the study area that includes the CR claim group; (2) areas of silicified and altered rock along the entire length of Castle Ridge, particularly the contact between the dark-green andesitic rocks and dark-red rhyolite; and (3) the area of First and Snowstorm Creeks along the western study area boundary where silicified and propylitically altered rocks were observed. This last area may extend as far southeast as Winters Creek and as far north as 2.5 mi north of First Creek.

The three zeolite outcrops examined in the study area require drilling to determine deposit size. Samples contained 46–70 percent zeolite (clinoptilolite). Grades as low as 40 percent have been found to be suitable for crude agricultural purposes. However, the present abundance of high-grade (on the order of 90 percent) zeolite deposits would require that low-grade deposits be close to markets.

The diatomaceous bed north of the study area contains 70–73 percent silica; most commercial diatomite has a silica content of more than 86 percent (Kadey, 1973). However, processing (calcining) of this material may decrease the contaminants and significantly increase the relative silica content. Further study is required to confirm the size of the deposit (43,000 tons) and to determine whether this material can be refined to commercial grade. Although the analytical methods used for this study are suitable for screening the general quality of material, the most reliable assessment of diatomite and zeolites involves bulk sampling and detailed physical and chemical tests for specific end uses (Glen Teague, oral commun., 1986).

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Alan R. Wallace, Robert L. Turner, V.J.S. Grauch, Joseph L. Plesha, M. Dennis Krohn, and Joseph S. Duval
U.S. Geological Survey

Geologic Setting

The Little Humboldt River Wilderness Study Area is between the volcanic-dominated Snake River Plain to the north and the structurally complex Basin and Range province to the south and west. In the Early Mississippian and again in the Late Permian (see geologic time chart in the appendix), eugeosynclinal chert, argillite, and related mafic volcanic rocks were thrust eastward along the Roberts Mountains and Golconda thrusts, respectively, over platform carbonate, shale, and quartzite. Additional east-directed deformation took place in the Late Mesozoic. As a result, the pre-Tertiary rocks in north-central Nevada are complexly interleaved and deformed.

In the transition zone between the Snake River Plain and Basin and Range province, extensive Tertiary volcanic rock units largely cover the pre-Tertiary sedimentary and igneous rocks. Pre-Tertiary sedimentary rocks are exposed less than 10 mi to the east and west of the study area, but only Tertiary volcanic and volcaniclastic rocks are exposed in and near the study area. A conjugate system of normal faults crosscuts the volcanic rocks.

The study area is along or at the intersection of several regional geologic and mineral deposit lineaments. The north-northwest-trending Oregon-Nevada lineament, marked by en echelon faults, silicic Miocene volcanic rocks, and a pronounced aeromagnetic anomaly (Stewart and others, 1975), is directly west of the study area. The northeast-trending Midas trough, part of the larger Humboldt structural zone and characterized by northeast-trending faults and linear features (Rowan and Wetlaufer, 1981), is directly south of the study area. Many of the known sediment-hosted disseminated gold deposits in Nevada are along the northwest-trending Carlin trend and the northeast-trending Getchell trend. When projected northward, these trends intersect just north of the study area.

Volcanic and Volcaniclastic Rocks

With the exception of minor Quaternary alluvium, complexly interbedded Miocene felsic and mafic volcanic and volcaniclastic rocks are the only units exposed in the study area. These units can be divided generally into rhyolitic and andesitic flows, tuff layers, and sedimentary rocks; the tuff of the Little Humboldt River; the rhyolite of Kelly Creek Mountain; undivided tuffaceous sedimentary rocks; and basalt flows of the the Big Island Formation (pl. 1).

The oldest sequence of volcanic rocks consists of rhyolitic tuff, tuffaceous sedimentary rocks, and basaltic andesite exposed along Castle Ridge to the east and on Snowstorm Mountain to the west (Tba, Tt, Tts, and Trt on pl. 1). All of the rhyolitic rocks contain sparse sanidine phenocrysts; the basaltic andesite contains small phenocrysts of plagioclase, olivine, and augite. Tuff and tuffaceous sedimentary rocks along Castle Ridge are overlain by basaltic andesite and rhyolitic ash-flow tuff. North-northeast-trending rhyolite domes formed on top of the older tuff layers. Arcuate faults near Snowstorm Mountain may be ring fractures related to explosive volcanic vents. These rhyolitic rocks are covered by the tuff of the Little Humboldt River throughout much of the study area, but the similarities between the Castle Ridge and Snowstorm Mountain sequences suggest that the two sequences are related. The basaltic andesite, as exposed along the Midas trough (fig. 2), was dated by the potassium-argon method at 15.1±1.6 Ma (E.H. McKee *in* Zoback and Thompson, 1978).

The tuff of the Little Humboldt River (Tlh on pl. 1) is exposed throughout much of the wilderness study area. A fission-track age on zircon indicates an age of about 13.7 Ma (A.R. Wallace, unpub. data, 1986). The tuff contains phenocrysts of plagioclase, sanidine, and sparse quartz and pigeonite in a fine-grained, gray-brown groundmass. It forms several cooling units, and its base is largely unexposed; it is at least 600 ft thick. Complex flow folds and foliation suggest that the tuff was erupted as a lava flow, but microscopic welding textures and preserved ash and pumice fragments attest to an explosive origin. In this regard, the tuff is similar to contemporaneous, high-temperature ignimbrites in south-western Idaho that, during emplacement, acquired the physical properties of lava (Ekren and others, 1984). The source of the tuff of the Little Humboldt River is unknown; it may have been erupted from vents now covered by the flows, or, because field evidence suggests that it thins to the south, it may have come from a source to the north. The tuff generally fills the north-trending basin between Castle Ridge and Snowstorm Mountain, and it ramps onto the two ridges and is also cut by the normal faults that formed the basin, suggesting that the tuff was erupted during formation of the basin. Several underlying welded tuff units exposed in the upper reaches of the Little Humboldt River canyon are chemically and physically similar to the tuff of the Little Humboldt River, but they contain more quartz than the later tuff.

The crystal-rich rhyolite of Kelly Creek Mountain (Tkc on pl. 1) is part of a regionally extensive series of lavas, ignimbrites, and domes to the west and southwest of the study area, and it overlies the tuff of the Little Humboldt River near First Creek at the west edge of the study area. Large phenocrysts of sanidine, quartz, and minor plagioclase constitute as much as 30 percent of the rock. The rhyolite was erupted from north-northwest-trending fissures, and flow was predominantly to the west; it is notably absent above the tuff of the Little Humboldt River in most of the study area. A potassium-argon age for the tuff is 13.4±0.4 Ma (E.H. McKee, written commun., 1986).

Tuffaceous sediments (Tts on pl. 1) were deposited in large to small basins throughout the Miocene volcanic cycle. Unconsolidated ash was washed into lakes by streams, and boulder-laden lahars descended into the basins from adjacent ridges. Some of the lakes were hypersaline, and zeolites and chert formed during diagenesis of the related lake beds (Sheppard and Gude, 1983). Fluvial reworking of the sediments is evident in many of the deposits.

Extensive basalt flows of the Big Island Formation (Tb on pl. 1) were erupted from shield volcanoes northeast of the study area, covering virtually all of the older volcanic rocks in that area. The basalt flows extend to the northeastern border of the study area, where they were in part erupted from the Haystack Peak vent, which has a potassium-argon age of 9.8±2.5 Ma (E.H. McKee, written commun., 1986).

Surficial Deposits

Small amounts of poorly sorted, unconsolidated alluvium are distributed along some stretches of the South Fork of the Little Humboldt River and its tributaries. However, the narrow canyon bottoms severely limit the sizes of these deposits.

Structure

The volcanic rocks were erupted during incipient extension of the crust in this part of the Basin and Range province. The initial Miocene extension direction was east-northeast–west-southwest, as evidenced by the orientations of dikes, and later extension was to the northwest, as evidenced by the orientations of grabens such as the Midas trough.

The rhyolitic rocks along castle ridge were in part erupted from vents and domes that were likely controlled by northwest- to north-trending faults. In the vicinity of Snowstorm Mountain, dikes have a north-northwest orientation, indicating a predominant east-northeast–west-southwest extension direction during volcanic activity in the study area. The graben in which the tuff of the Little Humboldt River was emplaced is bounded by north-northwest-trending normal faults. The tuff of the Little Humboldt River is cut by early north-northwest normal faults and later east-northeast normal faults, reflecting the change in the extension direction. The basalt flows to the north and northeast are largely unfaulted, whereas the silicic volcanic rocks to the west and south are cut by normal faults having thousands of feet of displacement.

Geochemistry

Methods

Fifty-eight stream-sediment and heavy-mineral-concentrate samples were collected within and adjacent to the study area. The samples were taken from the active alluvium in the stream channel, and they represent a composite of the rock and soil exposed in the drainage basin above the sample site. In addition, approximately 126 rock samples were collected from the wilderness study area.

The stream-sediment samples were collected from the active alluvium in the stream channel. Each sample was composited from several localities along a channel length of approximately 50 ft. The stream sediments were sieved through an 80-mesh screen and pulverized to a fine powder before analysis. The heavy-mineral concentrates were sieved through a 10-mesh screen and then panned until most of the quartz, feldspar, clay-sized material, and organic matter were removed. The remaining light minerals were separated from the heavy minerals with a heavy liquid (bromoform, specific gravity 2.8). The magnetite and ilmenite were removed from the material of specific gravity greater than 2.8 with an electro-magnet. The concentrates were ground to a fine powder before analysis. Stream sediments represent a composite of the rock and soil exposed upstream from the sample site. The heavy-mineral concentrate represents a concentration of ore-forming and ore-related minerals that permits determination of some elements that are not easily detected in bulk stream sediments (if ore-mineralization has occurred in the study area).

Rocks were taken from mineralized and unmineralized outcrop and stream float. Samples that appeared fresh and unaltered were collected to provide information on geochemical background values. Altered or mineralized samples were collected to determine the suite of elements associated with the observed alteration or mineralization. The rocks were crushed and pulverized to a fine powder before analysis.

The heavy-mineral concentrates, stream sediments, and rocks were analyzed for 31 elements by direct-current arc, semiquantitative emission spectrographic analysis (Grimes and Marranzino, 1968; Crock and others, 1983). The rocks were also analyzed for arsenic, bismuth, cadmium, antimony, and zinc (O'Leary and Viets, 1986), for gold (Thompson and others, 1968), and for mercury (Koirtyohann and Khalil, 1976). Analytical data and a description of the analytical techniques were provided by B.M. Adrian (unpub. data, 1987).

Geochemical Results

The analytical data from the stream-sediment samples showed 20 ppm (parts per million) arsenic at two widely separated sample sites in the southwestern and southeastern parts of the study area. The sample from the southeastern site was from a stream that drains an extensively altered area of volcanic rocks. The other sample was from a small basin that drains an area of unaltered rocks of the tuff of the Little Humboldt River.

The analytical data for the nonmagnetic fraction of the heavy-mineral-concentrate samples show tin values from 20 ppm to 1,000 ppm; in addition, three samples from drainage basins east of the study area contained 2,000 ppm or more of tin. These data are difficult to evaluate because they are not supported by the rock geochemical data, which show only one sample containing detectable tin (greater than 10 ppm).

The analytical data for rock samples show above-background amounts of arsenic and mercury north of Brush Creek in the southeastern part of the study area, on the west side of the South Fork of the Little Humboldt River approximately 1 mi upstream from its confluence with Snowstorm Creek, and in the vicinity of Snowstorm Mountain just west of the study area boundary. Slightly elevated concentrations of thallium, antimony, and barium are also associated with these areas. These elements are typical of epithermal gold-silver deposits (Silberman and Berger, 1985). All of the areas are underlain by altered rhyolitic and basaltic andesitic volcanic rocks (Trt, Tba, Tt, pl. 1). Gold and silver were not found in these rocks at concentrations above their detection limits (0.1 ppm and 0.5 ppm, respectively). However, analytical data of samples from the southeastern part of the study area collected and analyzed by a mining company show the presence of as much as 0.6 ppm gold, as well as concentrations of mercury and arsenic similar to those detected in the present study.

Geophysics

Gravity and Aeromagnetics

Gravity and aeromagnetic data were interpreted for the Little Humboldt River Wilderness Study Area. The gravity data were compiled from data available from the U.S. Department of Defense data bank (National Oceanic and Atmospheric Agency National Geophysical Data Center) and from Erwin (1980). The complete Bouguer gravity anomaly map (fig. 3) generally represents deviations in rock density from a standard value of 2.67 g/cm^3 (grams per cubic centimeter). The aeromagnetic data were obtained from U.S. Geological Survey (1968), flown east-west at a 1-mi flight-line spacing, and U.S. Geological Survey (1972), flown east-west at a 2-mi spacing. Both surveys were flown at 9,000 ft above sea level. The total-field aeromagnetic anomaly map (fig. 4) generally represents changes in the magnetic field caused by differences in the magnetic properties of rocks.

Both gravity and aeromagnetic data define only regional features because of the lack of detailed coverage. The study area is near the Oregon-Nevada lineament, defined on state gravity and aeromagnetic maps as a series of positive north-northwest-trending anomalies (Stewart and others, 1975; figs. 3, 4). The gravity expression of the lineament (fig. 3) is not as pronounced as the aeromagnetic expression. A northeast-trending gravity high (outlined in fig. 3) extends off the map to the southwest and coincides in part with the Getchell trend of disseminated gold deposits. It may indicate a major underlying structural feature.

The aeromagnetic feature associated with the Oregon-Nevada lineament in figure 4 is disrupted to the south by a sharply defined break at the edge of the Midas trough (Zoback and Thompson, 1978). The discontinuity follows a 2,000- to 3,000-ft escarpment along the north edge of the trough, suggesting that the effect may be due entirely to topography. The south edge of the trough is less well defined by topography and magnetic anomalies. The pronounced east-west magnetic grain in the northeast quarter of figure 4 may correlate with basalt feeder dikes. The gravity map (fig. 3) does not show these features.

Very simple profile models of the gravity and aeromagnetic data across the study area were tested using very limited rock-property data (six samples). The data suggest that the rhyolite of Kelly Creek Mountain (Tkc) and the tuff of the Little Humboldt River (Tlh) have similar densities, close to 2.05 g/cm^3, whereas the rhyolitic to andesitic tuffs (Trt) may have densities closer to 2.30 g/cm^3. The magnetic data suggest that the rhyolite of Kelly Creek Mountain and the older rhyolitic to andesitic tuffs have total magnetizations that are an order of magnitude greater than that of the tuff of the Little Humboldt River, although the influence of lightning strikes may have obscured these determinations. If these rock-property values are representative of their associated units, then the modelling indicates that the aeromagnetic and gravity features can easily be explained by a cover, as much as 1,000 ft thick, of the tuff of the Little Humboldt River over the rhyolitic and andesitic tuffs. No loss of magnetism or density that might be related to alteration of the older tuffs is indicated. However, a detailed rock-property study is needed to determine if the measured values given here are representative.

Remote Sensing

Landsat Thematic Mapper (TM) data for the study area were analyzed to identify and evaluate possible areas of hydrothermal alteration. Techniques and their applications to the study of hydrothermal mineral deposits in Nevada are described in Krohn (1986). The surface distribution of hydrothermally

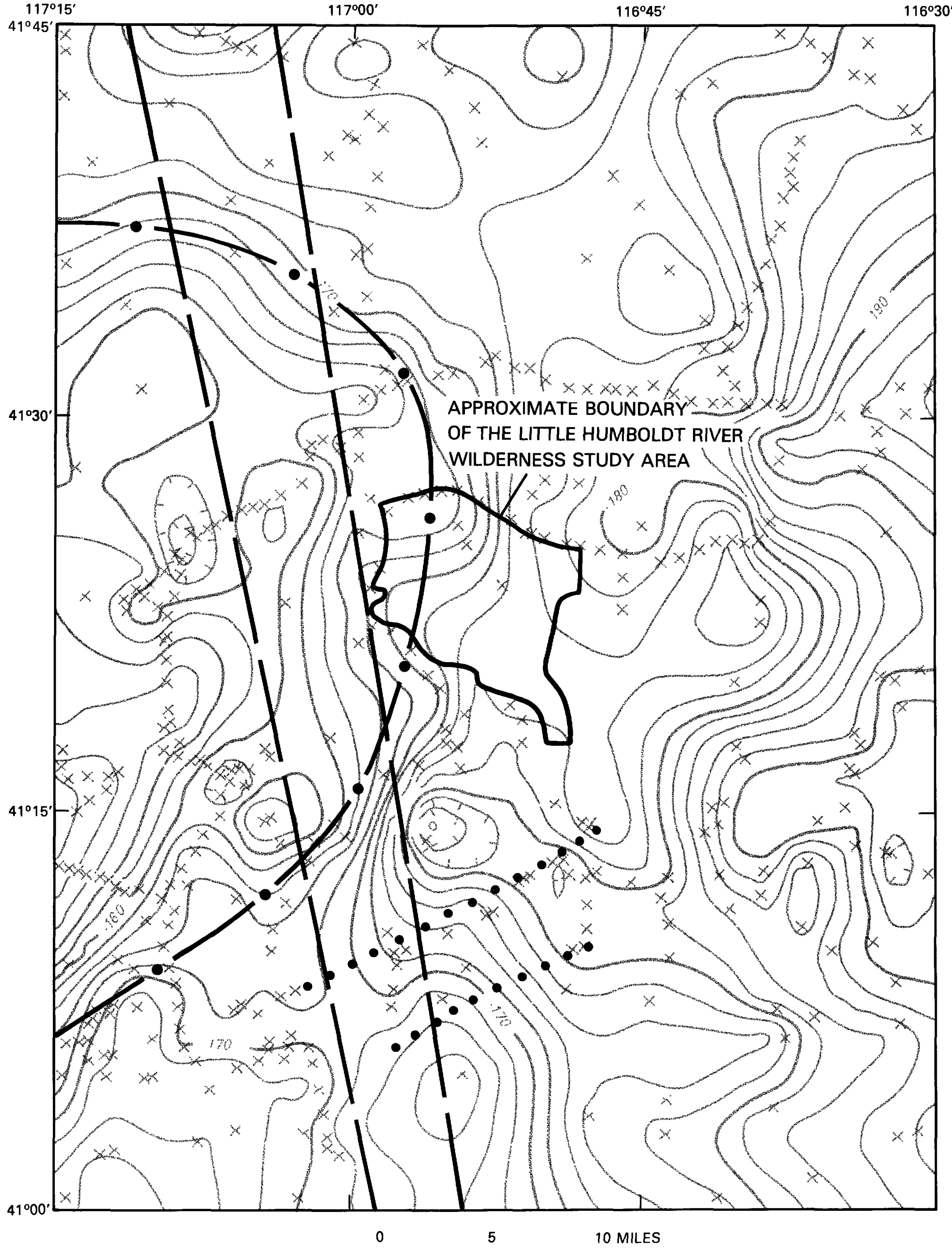


Figure 3. Complete Bouguer anomaly map of the Little Humboldt River Wilderness Study Area and vicinity, Elko County, Nev. Contour interval 2 milligals; hachured lines indicate area of closed gravity low. Reduction density 2.67 g/cm^3. Study area is shown by heavy solid line, the northern Nevada rift by long-dashed line, and the Midas trough by dotted line. Gravity high encircled by dash-dot line is discussed in the text. Gravity station is indicated by x.

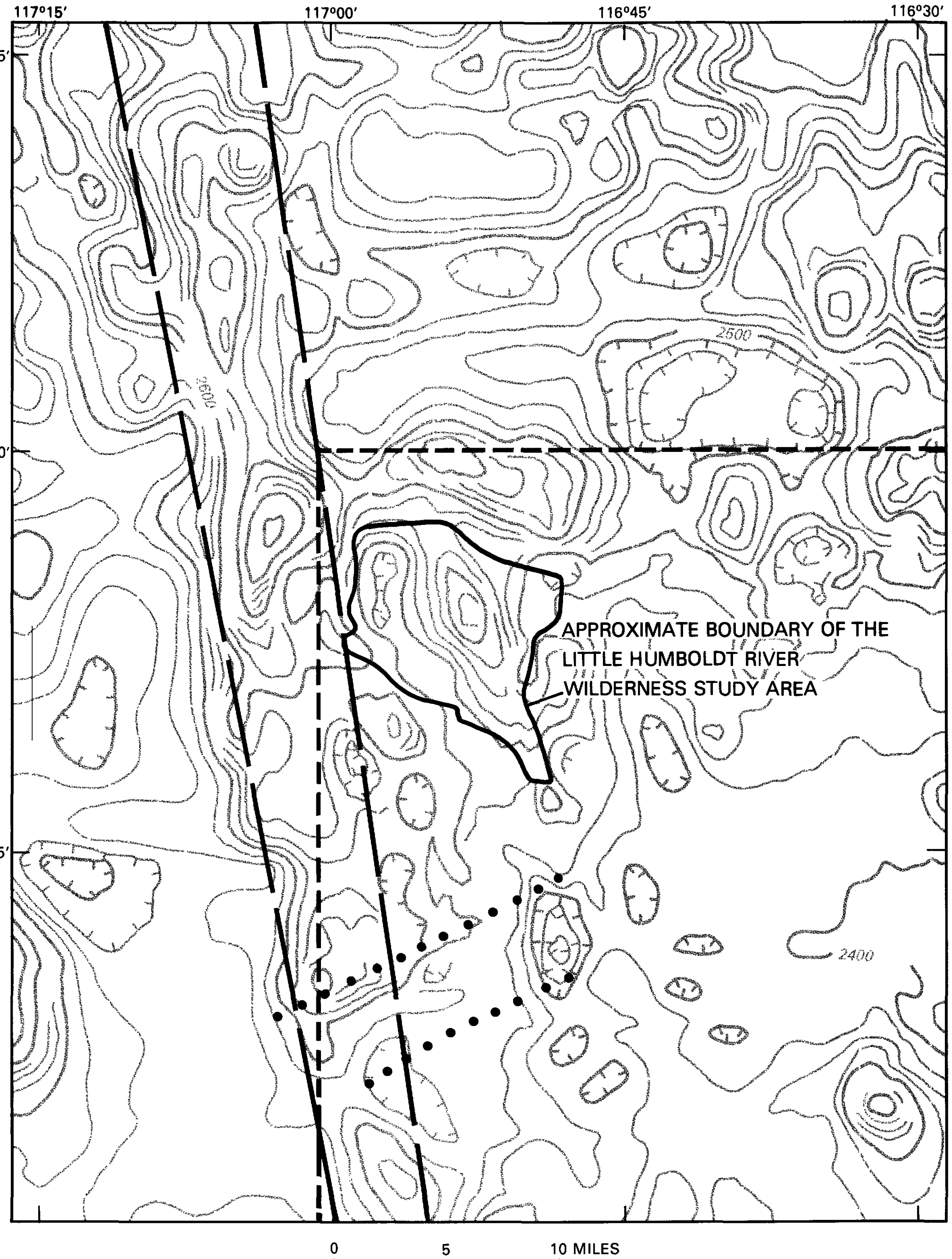


Figure 4. Total-field aeromagnetic map of the Little Humboldt River Wilderness Study Area and vicinity, Elko County, Nev. Compiled from surveys flown east-west at 9,000 ft above sea level. The survey in the southeast corner, outlined by the short-dashed line, had a 1-mi flight spacing, whereas the rest of the area had a 2-mi spacing. Contour interval 10 nanoteslas; hachured lines indicate area of closed magnetic low. Study area is shown by heavy solid line, Oregon-Nevada lineament by long-dashed line, and the Midas trough by dotted line.

altered rocks, which commonly contain iron oxides and clay minerals, can be mapped on the basis of their characteristic visible and near-infrared spectral properties. A color-ratio composite Landsat TM image was processed to display limonite and clay mineral absorption features. Landsat data were originally compiled at 1:250,000 and then enlarged to 1:100,000 for this study.

The vegetation response in the longer wavelengths affects the discrimination of other spectral features in vegetated areas. In Nevada, these areas are generally at higher elevations and on north-facing slopes. The western part of the wilderness study area could not be mapped due to the vegetation cover.

A map of alteration patterns identified from the TM color-ratio composite images is shown in figure 5. Two types of alteration patterns are shown, the most common of which is based on iron minerals. The TM also includes limonitic areas that are not hydrothermally altered. Field evidence shows that the TM discriminates rocks having dense, light-tan limonitic coatings. Several areas of clay minerals shown are based on the absorption of the 2.2-micron wavelength.

The remote-sensing data indicate that the highest concentration of hydrothermally altered rocks is immediately east of the confluence of First Creek with the Little Humboldt River, in the tuffaceous sedimentary rocks (Tts; pl. 1). Along the west side of Castle Ridge, small patterns of rocks having 2.2-micron absorption features are intermixed with limonitic rocks. These areas suggest the presence of clay minerals derived from argillic alteration. The patchy pattern is characteristic of areas that have undergone hydrothermal alteration.

Other, larger areas of iron oxide absorption features were observed west of the Little Humboldt River in areas underlain by the tuff of the Little Humboldt River (Tlh; pl. 1). The rocks are not hydrothermally altered, but have a dense, light-tan limonite surface coating. Many of the limonitic areas are on the south-facing hillsides, which tend to have less vegetation and more talus than other areas.

Several areas of iron oxides and clay minerals were detected in the northern part of the study area. These anomalies occur primarily in rhyolitic and andesitic tuffs (Trt) and tuffaceous sedimentary rocks (Tts; pl. 1). Quartz-rich volcaniclastic rocks commonly have iron-oxide coatings; however, a 2.2-micron absorption feature is unusual and presently not explained.

Aerial Gamma-Ray Spectroscopy

Aerial gamma-ray spectroscopy provides estimates of the near-surface (0–20 in. deep) concentrations of percent potassium (K), parts per million equivalent uranium (eU), and parts per million equivalent thorium (eTh). These data (K, eU, eTh) provide a partial geochemical representation of the near-surface materials.

The aerial gamma-ray data for Nevada were compiled and processed at a scale of 1:1,000,000. The resulting map was then examined to estimate the K, eU, and eTh concentrations for the study area and to note the occurrence or absence of anomalous radio-element concentrations. One of these elements is considered to be anomalous when the level of concentration, as well as its ratios to the other two elements, are all high values in the context of the map area.

The Little Humboldt River Wilderness Study Area has overall moderate radioactivity, with values of 1.5–2.5 percent K, 2–4 ppm eU, and 7,011 ppm eTh. There are no anomalies within the boundaries of the study area or in the immediate vicinity.

Mineral and Energy Resources

In evaluating the mineral and energy resource potential of the Little Humboldt River Wilderness Study Area, we have considered the characteristics of each of the deposit types in the region and compared them with the geologic, geochemical, and geophysical data acquired during this study. On the basis of how closely the data met the identifying criteria for each of the deposit types, we assigned high, moderate, low, no, or unknown levels of resource potential for each deposit type along with the level of certainty for each assessment (fig. 1).

The mineral resource deposit types that meet favorable assessment criteria and for which information is adequate to make an assessment are (1) disseminated gold deposits in volcanic rocks, and (2) zeolites in tuffaceous sedimentary rocks.

In addition, a low resource potential with certainty level D can be assigned for tin, uranium and thorium, oil and gas, and sand and gravel, and with certainty level C can be assigned for antimony, mercury, silver, arsenic, geothermal energy, and diatomite. Owing to the thick cover of Tertiary volcanic rocks in the area, the potential for bedded barite and disseminated gold deposits in underlying pre-Tertiary rocks is unknown.

Disseminated Gold Deposits

Deposit Characteristics

Volcanic-hosted gold-silver deposits in the Western United States are associated with silicic to andesitic volcanic and volcaniclastic rocks predominantly of Tertiary age (Buchanan, 1981). Faults acted as conduits for hydrothermal fluids, and concurrent fault movement and hydrothermal brecciation increased the permeability of the host rocks. The volcanic rocks were intensely silicified at upper levels and near the fractures; the alteration haloes contain quartz, sericite, clay minerals, chlorite, pyrite, adularia, and calcite. Native gold and mercury, as well as pyrite, sulfosalts, sulfides, quartz, adularia, and alunite, formed in fractures and were disseminated through the host rocks. The hydrothermal minerals are submicroscopic to coarse grained depending upon the conditions of mineralization. Subsequent erosion and supergene oxidation of the deposit enriched the upper mineralized zones, and oxidation of iron sulfides and oxides generated red to yellow iron oxides and sulfates at the surface.

Stream-sediment and rock samples can identify and define the lateral extent of an orebody. Unless analytical techniques achieving extremely low (less than 100 ppb) detection limits are used, gold may not be detected in reconnaissance surveys. However, arsenic, antimony, mercury, and thallium, which commonly are associated with gold in epithermal gold deposits, may be present in sufficient amounts to be detected. Dispersive haloes around individual veins may not produce anomalies in stream-sediment samples, whereas larger disseminated or stockwork deposits are more likely to be detected in stream-sediment surveys.

Various geophysical methods can be applied to the evaluation of mineralized areas. Aeromagnetic surveys can identify areas where the primary magnetic minerals in a large volume of rock have been destroyed by hydrothermal alteration, presuming that significant quantities of those minerals were originally present. Gravity surveys can detect areas where alteration has produced a density contrast in the rocks. Remote-sensing studies can delineate areas of iron oxide staining that might indicate hydrothermal alteration. Radiometric surveys can identify areas where uranium and potassium have been introduced to mineralized areas during hydrothermal activity.

Resource Potential

Two areas in the Little Humboldt River Wilderness Study Area have a high potential for gold resources in a disseminated deposit: (1) in the southeastern part of the study area in the vicinity of Brush Creek (certainty level D), and (2) along Snowstorm Creek at the west edge of the study area (certainty level C). A third area, along the South Fork of the Little Humboldt River roughly from the confluence of First Creek upstream to 1 mi above the confluence of Snowstorm Creek, has amoderate potential at certainty level C for goldresources in a disseminated deposit. The areas were identified on the basis of geological mapping and geochemical sampling, and the remote-sensing data confirmed the alteration zone along the South Fork of the Little Humboldt River. The reconnaissance nature of the gravity and aeromagnetic studies did not assist in delineating these areas.

Brush Creek Area

The rocks in this area form a complexly interlayered sequence of Tertiary rhyolitic volcanic rocks and tuffaceous sedimentary rocks that were cut by steeply dipping, north- and east-trending faults of unknown displacement. The rocks were pervasively altered in an elongate, two-square-mile zone roughly coincident with two north-trending fault zones. Most of the rocks have undergone argillic alteration, which produced a bleached rock containing quartz, sericite, clay minerals, and pyrite.

The most intensely altered and fractured rocks are on either side of Brush Creek at the extreme southeastern end of the study area. The rocks on either side of the creek were weakly to pervasively silicified, and brecciated rocks along the fault zones were cemented by quartz and chalcedony. The silicified and altered rocks are cut by numerous thin veinlets of gray chalcedony, locally containing small amounts of alunite. Most of the original pyrite was destroyed by hydrothermal or weathering-related oxidation, which imparted a distinct yellowish-red color to the rocks.

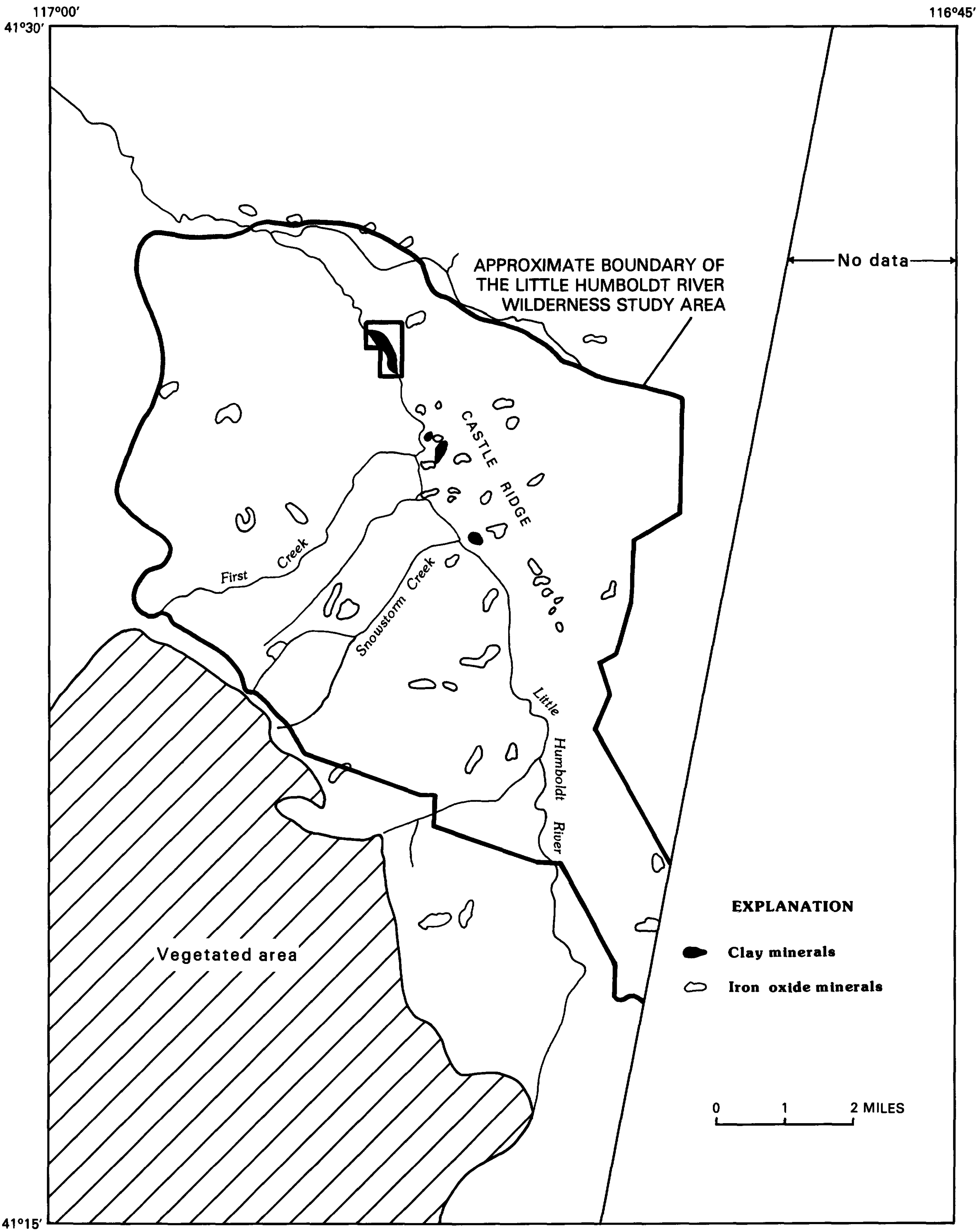
Rock samples collected in the altered zone contain anomalous amounts of mercury, arsenic, thallium, and antimony relative to similar rocks outside the zone of alteration. Gold was not detected, possibly due to the relatively high (0.1 ppm) detection limit. However, small amounts of gold were detected in silt-size stream-sediment samples collected and analyzed by a major mining company. In addition, rock samples collected and analyzed by the USBM contained anomalous amounts of gold (Gabby, 1987).

The mineralized area is 2 mi north of the Midas district, where silver-rich ores were mined from northwest-trending veins (Rott, 1931). The veins at Midas formed at approximately 15 Ma (McKee and others, 1976), and the host rocks are part of the same volcanic sequence exposed in the Brush Creek area. The Brush Creek area has high mineral resource potential for gold, with certainty level D.

Snowstorm Creek Area

Extremely silicified, altered, and brecciated rhyolitic rocks are exposed in the vicinity of Snowstorm Creek just west of the study area. Exposures of the mineralized older rhyolitic rocks along Snowstorm Creek are covered by the tuff of the Little Humboldt River just inside the boundary of the study area, and the continuation of the mineralized zone into the study area is likely.

The volcanic rocks exposed immediately west of the study area include rhyolitic ash-flow tuffs, domes, tuffaceous sedimentary rocks, and poorly welded tuffs (Trt; pl. 1). The rocks are cut by a poorly exposed, arcuate ring fracture along which Snowstorm Creek has



been incised and by north-trending normal faults. The volcanic rocks within a few hundred yards of the ring fracture have been altered to an argillic assemblage, and many of the rocks, especially along or near the faults, are intensely silicified. The rocks within the arc of the ring fracture are altered and silicified, and they locally contain pyrite in veinlets and as disseminations through the silicified rocks. Quartz veinlets as much as 0.5 in. wide are common throughout the entire altered area.

The mineralized zone and related ring fracture are cut on the east side by north-trending normal faults related to the graben filled by the tuff of the Little Humboldt River. Unaltered remnants of this tuff on the west side of the fault zone overlie altered older tuff; this relationship implies a pre-Little Humboldt age for mineralization. On the east side of the fault zone, the tuff of the Little Humboldt River is unmineralized, and altered older tuffs presumably underlie this tuff at an unknown depth. The extent of this underlying altered zone beneath the study area is unknown. However, the curved projection of the ring fault and related alteration across the north-trending fault zone would extend for about 0.75 mi into the study area south of Snowstorm Creek.

Rock samples collected from the altered zone contain anomalous amounts of mercury and arsenic relative to unaltered older tuffs in the Snowstorm Mountain area. USBM samples contained anomalous amounts of gold (Gabby, 1987). A heavy-mineral concentrate from Snowstorm Creek at the study area boundary contained anomalous concentrations of silver, copper, lead, and tin. The Snowstorm Creek area has high mineral resource potential for gold, with certainty level C.

Areas Adjacent to the South Fork of the Little Humboldt River

Silicified, brecciated, and bleached rocks are exposed along the east side of the South Fork of the Little Humboldt River roughly from the confluence of First Creek to 1 mi south of the confluence of Snowstorm Creek. The rocks are predominantly light-colored, poorly welded tuffs and tuffaceous sedimentary rocks interlayered with locally abundant lahar (mudflow) deposits. They are overlain by the tuff of the Little Humboldt River and they have been cut by north-northwest-trending normal faults. Similar rocks are present locally on the west side of the river south of Snowstorm Creek. Silicified and argillically altered rocks are most pronounced adjacent to the faults, and fault segments are locally cemented by chalcedony and pyrite. Veinlets are sparse and are filled with gray chalcedony. Evidence of pervasive alteration is obscure: the rocks were originally light colored and were composed of clay minerals and diagenetic silica minerals that are difficult to distinguish in the field from hydrothermal alteration minerals. The overlying tuff of the Little Humboldt River is notably fresh. Remote-sensing data confirm the observations that the tuffaceous sedimentary units have been hydrothermally altered.

The extent of this brecciated and altered zone beneath the tuff of the Little Humboldt River is unknown. It appears to be related to faults that cut the rock, but the extent of these faults beneath the younger volcanic rocks cannot be predicted.

Rock samples for 1 mi upstream from the confluence of Snowstorm Creek contain anomalous amounts of arsenic and mercury, an assemblage suggesting the presence of gold in quantities below the analytical detection limit. The mineral resource potential for gold in this area is moderate, with certainty level C.

Additional Areas

At the three areas described above, mineralization is inferred to have taken place prior to the emplacement of the tuff of the Little Humboldt River: the older rocks are mineralized, whereas the overlying tuff of the Little Humboldt River is not. In the study area, the older sequence of volcanic rocks may be locally mineralized, but centers of mineralization are difficult to identify through the thick cover of younger tuffs. Those areas where the older volcanic sequence is buried have an unknown mineral resource potential for disseminated gold deposits.

Minor amounts of silicified and altered rock are locally associated with normal faults that cut the tuff of the Little Humboldt River, and some zones contain weakly anomalous concentrations of trace elements. A rock sample from an altered fault zone 1.4 mi south of Rodear Flat, near the north end of the study area, contained 0.21 ppm mercury but only background levels of thallium, arsenic, and antimony. A silt sample collected 2.8 mi south of Rodear Flat by a major mining company contained 20 ppb gold and 20 ppb mercury; the sample site is near a weakly silicified zone in the tuff. Both altered and silicified areas are extremely small, and they have a low mineral resource potential at certainty level C for disseminated gold deposits.

Isolated samples collected by the USBM from north of the mineralized Brush Creek area contain anomalous amounts of gold (Gabby, 1987), whereas USGS samples from the same areas did not contain any

Figure 5 (facing page). Map showing areas of possible hydrothermally altered rocks outlined on the basis of spectral analysis of Landsat Thematic Mapper (TM) color-ratio composite images, Little Humboldt River Wilderness Study Area, Elko County, Nev. Areas of potential clay minerals suggest argillic alteration. Western part of area could not be mapped due to relatively abundant vegetation. Landsat scene id 50137–17552 was acquired on 7/16/84. Image was processed as a color-ratio composite of band 5/band 7, band 3/band 1, and band 5/band 4. Drainage is based on U.S. Geological Survey quadrangle maps modified from Landsat images.

related elements in anomalous amounts. Altered rocks are restricted to a thin basal rhyolite breccia, and underlying and overlying rocks are not altered. As noted by Gabby (1987), these weakly mineralized areas may be related to the main hydrothermal center near Brush Creek. However, surface exposures indicate that the area affected is small, and evidence of pervasive silicification and alteration, associated trace elements, and veinlets are absent. Therefore, this area has a low mineral resource potential, at certainty level C, for disseminated gold deposits.

Paleozoic carbonate rocks, if present beneath the volcanic rocks in the study area, may contain low-grade, high-tonnage disseminated gold deposits similar to those in the nearby Carlin and Getchell gold trends (Bagby and Berger, 1985). However, pre-Tertiary rocks are not exposed in the study area, and the mineral resource potential for a disseminated gold deposit in pre-Tertiary sedimentary rocks is unknown.

Zeolites

Zeolites form during diagenesis of silicic tuffs and tuffaceous sediments as pore waters interact with glass shards and ash in the units (Sheppard and Gude, 1983). Chert and potassium feldspar can also form during diagenesis. The mineralogy of the resultant assemblage is strongly dependent upon the chemistry of the pore fluids because water in a highly saline and alkaline lacustrine environment will produce a suite different from one formed in more dilute waters having nearly neutral acidity.

Poorly consolidated tuffaceous sedimentary rocks are exposed in several parts of the study area, although most of the deposits are very small. Extensive deposits of Miocene lacustrine sediments 4 mi northwest of the study area contain significant quantities of the zeolites clinoptilolite and erionite (Sheppard and Gude, 1983). A similar section of tuffaceous rocks is exposed on the east side of the South Fork of the Little Humboldt River at the mouth of First Creek. These yellowish tuffaceous rocks are weakly to strongly lithified, and they contain interbeds of welded tuffs and lahar deposits. X-ray diffraction analyses of the rocks, as well as USBM data (Gabby, 1987), indicate that they contain significant quantities of clinoptilolite. This area has a high mineral resource potential for zeolites, at certainty level D.

Tuffaceous sedimentary rocks blanket the northeastern corner of the study area. Although these units contain significant amounts of coarser, nonlacustrine sedimentary rocks, the sequence as a whole is similar in lithology and depositional environment to those areas northwest of the study area and at the mouth of First Creek. However, chert and zeolitic tuffs were not readily identified in the poor exposures. This area therefore has a moderate mineral resource potential, at certainty level B, for zeolites. The remainder of the study area has a low potential, at certainty level D, for zeolites.

Barite

Sedimentary barite deposits form when barite is precipitated from ocean water in deep-water marine environments. In northern Nevada, barite deposits formed during deposition of lower and middle Paleozoic siliceous sedimentary rocks (Papke, 1984). Sedimentary barite deposits are exposed in the Osgood Mountains to the southwest of the study area and at the Rossi mine 23 mi to the southeast. The Valmy Formation, a known host for barite deposits (Papke, 1984), is exposed 10 mi to the southwest and 9 mi east of the study area; on the basis of the regional distribution of the rocks, the Valmy may be considered to extend beneath the Tertiary volcanic rocks in the study area. However, the known barite deposits are scattered, and the presence of the host formations does not guarantee the occurrence of sedimentary barite. Therefore, although the favorable host rocks may extend beneath the study area, the occurrence of barite within that particular package of rocks is only speculative. As a result, the mineral resource potential for sedimentary barite beneath the volcanic rocks in the study area is unknown.

Tin

Tin, primarily as the mineral cassiterite, is locally associated with alkali-rich rhyolitic flows and domes in the Western United States. The cassiterite can form directly from the crystallizing magma as a trace mineral, and it can form veins, with quartz, that cut the volcanic rocks. Because cassiterite is a dense, heavy mineral, chemical analyses of the heavy-mineral concentrate of a stream-sediment sample will detect the presence of cassiterite.

Cassiterite was not observed in the volcanic rocks in the study area, and analyses of rock samples did not detect tin above the analytical detection limit of 10 ppm. However, many of the heavy-mineral concentrates collected in the study area contain anomalous concentrations of tin, suggesting that the volcanic rocks contain trace amounts of cassiterite. Tin-bearing veinlets cut volcanic rocks 25 mi southwest of Midas (Fries, 1942), but similar veins were not found in the study area. Therefore, the mineral resource potential for tin deposits in the entire study area is low, at certainty level D.

Other Metals

Arsenic, antimony, silver, and mercury are trace elements commonly associated with disseminated, hydrothermal gold deposits. In places, these elements may be sufficiently abundant to be mined, or they may be extracted during processing of gold ore. The geological, geochemical, and geophysical characteristics of these deposits are similar to those for disseminated gold deposits. Arsenic, antimony, and mercury are typically found in the upper, near-surface zones of hydrothermal systems, and the concentrations of the element in the fluid and various mechanisms of ore deposition can lead to the enrichment of a gold deposit in these metals.

The areas that have high or moderate mineral resource potential for disseminated gold deposits were identified on the basis of arsenic, antimony, silver, and mercury trace-element signatures. However, the concentrations of these metals are minor. Therefore, the mineral resource potential for arsenic, antimony, silver, and mercury is low for the entire study area, at certainty level C.

Geothermal Energy

Increased heat flow from igneous activity or thinning of the crust can increase the temperature of ground water. The heated waters, having temperatures from about 70 °C to more than 200 °C, may debouch at the surface to form hot springs, or they may remain trapped at depth.

Part of north-central Nevada is an area of high heat flow, referred to as the "Battle Mountain high" (Sass and others, 1971), which contains numerous hot springs that have been tapped for geothermal energy. Hot springs have been reported 12 mi and 25 mi west of the study area along the Little Humboldt River (Waring, 1965). A hot spring was reported to be at the "head of the South Fork of Little Humboldt River," but disparate townships and ranges given for the spring place it either 30 mi to the west in the Hot Springs Range (Waring, 1965) or several miles west of Midas, along the Midas trough (Garside and Schilling, 1979), a location several miles south of the headwaters of the South Fork of the Little Humboldt River.

The study area is near the northern edge of the Battle Mountain geothermal high, but all of the numerous springs in the study area are cold. The study area has a low potential for geothermal energy, at certainty level C.

Oil and Gas

Ordovician sedimentary rocks in western Nevada, including the Vinini and Valmy Formations, are potentially good source rocks for petroleum (Sandberg, 1983). However, in the vicinity of the study area, the rocks have been complexly deformed and metamorphosed during several pre-Tertiary tectonic events. In addition, extremely high temperatures related to Tertiary volcanism and modern high heat flow related to the Battle Mountain geothermal high have probably overmatured the Paleozoic sedimentary rocks. As a result, the study area has a low energy resource potential, at certainty level D, for oil and gas. Sandberg (1983) rated the study area as having "zero potential" for petroleum.

Sand and Gravel

Sand and gravel are deposited from streams when the streams lose their ability to move the materials. Within the study area, small, scattered deposits of sand and gravel formed along some stretches of the South Fork of the Little Humboldt River and its tributaries. The mineral resource potential for undiscovered sand and gravel deposits is low, at certainty level D.

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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.

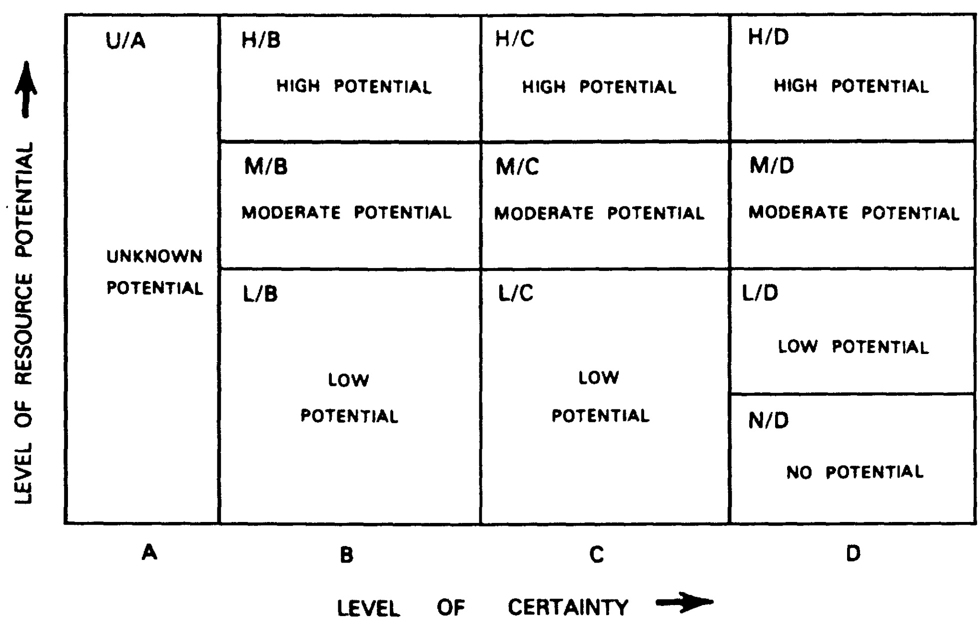
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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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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