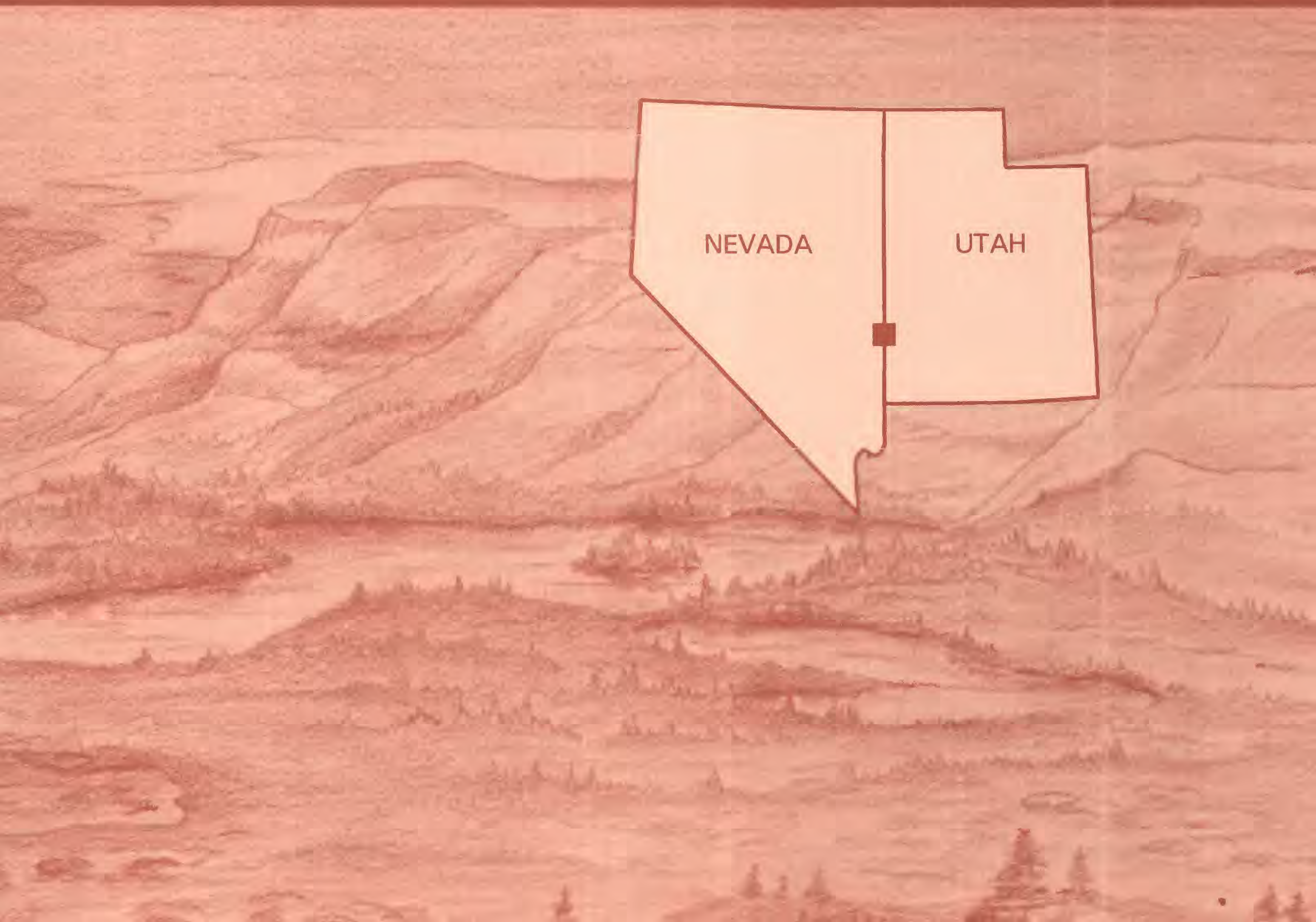
Mineral Resources of the White Rock Range Wilderness Study Area, Lincoln County, Nevada, and Beaver and Iron Counties, Utah

U.S. GEOLOGICAL SURVEY BULLETIN 1728–B



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.

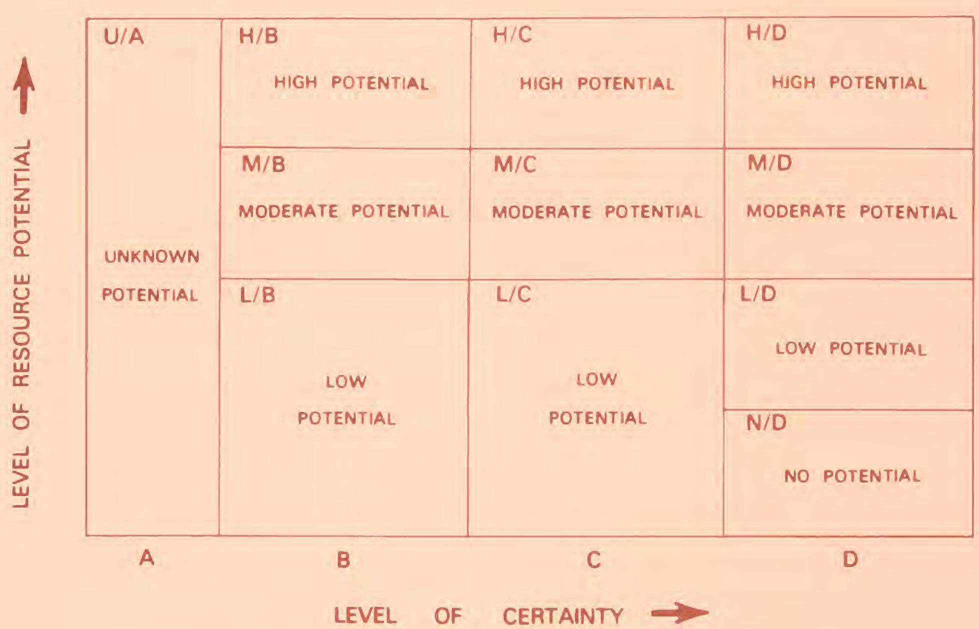
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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

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

Chapter B

Mineral Resources of the White Rock Range Wilderness Study Area, Lincoln County, Nevada, and Beaver and Iron Counties, Utah

By MARGO I. TOTH, REBECCA G. STONEMAN, and
H. RICHARD BLANK, JR.
U.S. Geological Survey

DIANN D. GESE
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1728

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
EAST-CENTRAL NEVADA AND PART OF ADJACENT
BEAVER AND IRON COUNTIES, UTAH

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of a part of the White Rock Range (NV-040-202/UT-040-216) Wilderness Study Area, Lincoln County, Nevada, and Beaver and Iron Counties, Utah.

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.

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EAST-CENTRAL NEVADA AND PART OF
ADJACENT BEAVER AND IRON COUNTIES, UTAH

Mineral Resources of the White Rock Range Wilderness Study Area, Lincoln County, Nevada, and Beaver and Iron Counties, Utah

By Margo I. Toth, Rebecca G. Stoneman, *and* H. Richard Blank, Jr.,
U.S. Geological Survey, *and*
Diann D. Gese, U.S. Bureau of Mines

SUMMARY

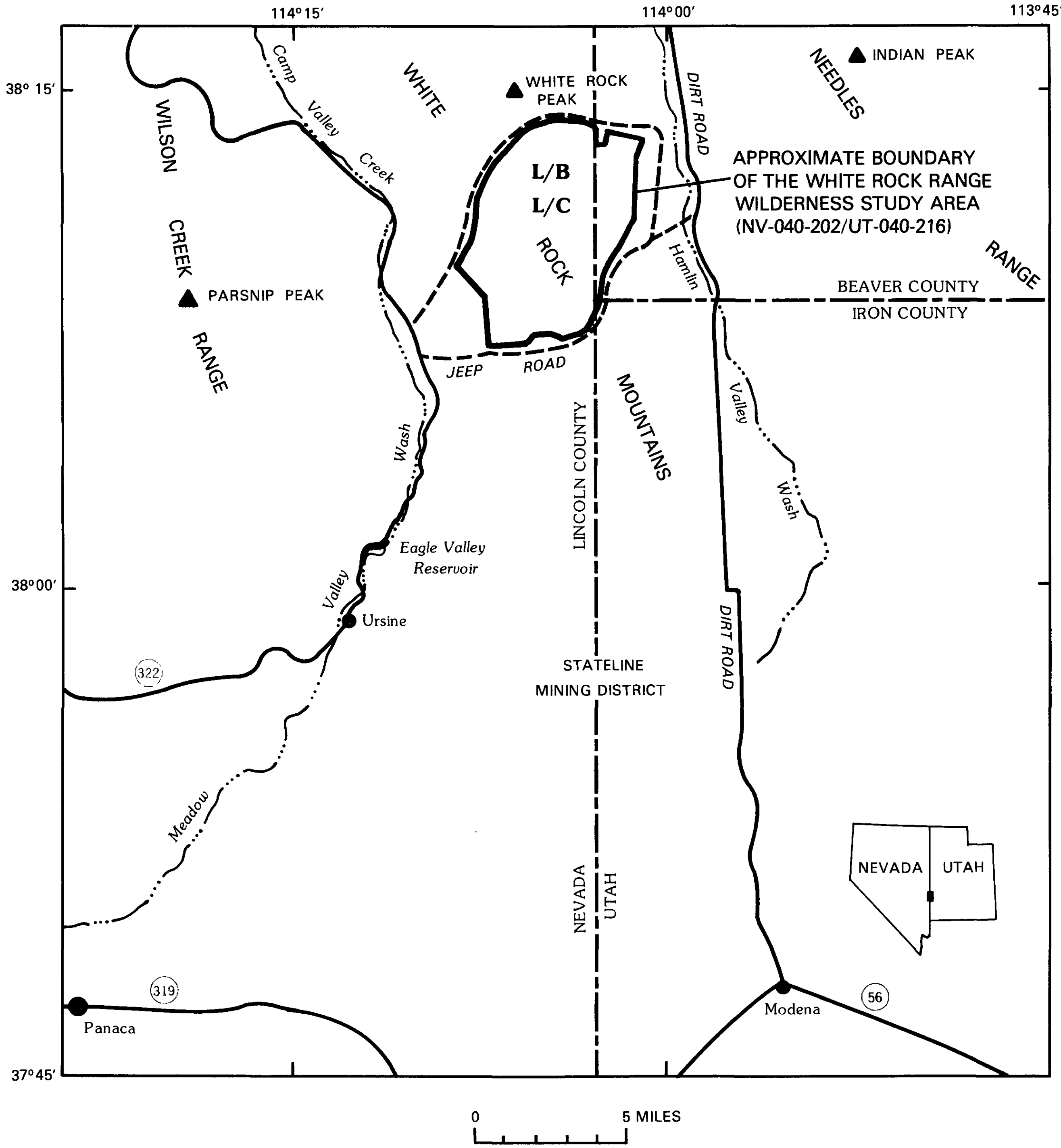
The White Rock Range Wilderness Study Area (NV-040-202/UT-040-216) is in Lincoln County, Nevada, and Beaver and Iron Counties, Utah, along the southern Nevada-Utah state line. Ursine, the town nearest to the study area, is about 15 mi (miles) southwest of the study area; the larger town of Pioche is about 30 mi southwest of the study area on Nevada Highway 322 (fig. 1). A joint mineral resource appraisal of the 23,625-acre wilderness study area was completed in the summers of 1984 and 1985 by the U.S. Geological Survey and U.S. Bureau of Mines. The White Rock Range Wilderness Study Area has no identified mineral resources and has low mineral resource potential for metals; the potential for oil and gas, coal, and geothermal energy is also low.

Access to the study area is provided by unpaved roads which approach the study area from the eastern and western sides. Most of these roads are passable by four-wheel-drive vehicle during the drier months of the year. Game trails cross the area but are commonly obscured in the more heavily vegetated areas; no other established trails are present.

The White Rock Range Wilderness Study Area is along the eastern margin of the Basin and Range Province and is also within the Blue Ribbon lineament, a major east-trending structural zone in southern Nevada and Utah. In the study area and vicinity, widespread silicic volcanic rocks of Oligocene age unconformably overlie eroded remnants of deformed Paleozoic and Mesozoic sedimentary rocks; the northern end of the study area lies along the northeastern margin of the Wilson caldera. The study area contains a thick section of Oligocene volcanic rocks, flanked on the west by Tertiary lake sediments; extensive colluvial deposits are developed along the western and eastern sides. The volcanic rocks in the study area consist of the Lund Formation of the Needles Range Group, the tuff of Ripgut Springs, the Isom Formation, the Bauers Tuff Member of the Condor Canyon Formation, and tuff and rhyolite flows of the Blawn Formation. A veneer of andesite overlies the volcanic rocks near White Rock Peak, and rhyolite flows crop out just to the east of the study area. Many northeast- and northwest-trending faults crossing the area have offsets from a few feet to more than several hundred feet; abundant springs commonly occur along the faults or at the intersection of faults.

No mining activity has occurred in the wilderness study area, and no mineralized areas were identified. Small gold and silver breccia veins are 500 ft (feet) southeast of the study area in sheared and faulted parts of the Isom Formation. The veins contain gold ranging from trace amounts to 0.10 oz/ton (ounce per ton) and silver ranging from 0.1 to 0.2 oz/ton. However, no mineralized rock was found in the study area.

As a part of this study, stream-sediment and rock samples from the study area were collected for analysis. Panned-concentrate samples of stream sediments contained anomalous concentrations of tin, lead, and molybdenum, but the sources of these anomalies were not located in outcrop. Cassiterite and galena were identified in the panned-concentrate samples containing high tin and lead, but they were not identified in any rock samples. The fine fraction of the stream-sediment samples did not contain any anomalous concentrations of the analyzed elements. Three rock samples from the study area contained



EXPLANATION

L/B **Geologic terrane having low mineral resource potential for metals and geothermal energy, with certainty level B**

L/C **Geologic terrane having low mineral resource potential for oil, gas, and coal, with certainty level C**

Figure 1. Map showing mineral resource potential and location of the White Rock Range Wilderness Study Area, Nevada and Utah.

anomalous molybdenum (5–7 ppm, parts per million), but no other base or precious metals were present in anomalous concentrations. Five hundred feet southeast of the study area, sheared and mineralized rock of the Isom Formation contained anomalous amounts of silver (5 and 7 ppm).

Aeroradiometric data indicate moderate radioactivity for the rocks in the study area; average values are 2.5–3 percent potassium, 20–35 ppm equivalent uranium, and 10–15 ppm equivalent thorium. The study area has a prominent positive aeromagnetic anomaly with several superimposed local maxima. The major anomaly reflects strongly magnetic volcanic rock, probably either vitrophyric ash-flow tuff or hypabyssal intrusive rocks. On a regional scale, east-trending aligned aeromagnetic highs pass through the area. These highs are associated with a known deep crustal fracture which has been a locus of volcanism, hypabyssal intrusions, and hydrothermal activity. North-trending belts of steep gravity gradients on both sides of the White Rock Mountains reflect range-front faults; volcano-tectonic structures also influence gravity anomalies on the west. The entire study area lies in a broad elliptical gravity depression, which is associated with the Wilson Creek caldera. Arcuate gravity and aeromagnetic features may be related to associated ring fractures of the caldera.

The White Rock Range Wilderness Study Area has low mineral resource potential for all metals (fig. 1). Although geophysical data suggest that the study area should be regarded as favorable for mineral deposits, no mineralized areas were identified. The mineral resource potential for oil, gas, and coal is also low. Paleozoic sedimentary rocks may underlie the study area and could be a reservoir for oil and gas; however, the thickness of the overlying volcanic sequence is presently unknown, and the nature of the underlying sediments is uncertain. Any hydrocarbons associated with the sedimentary rocks could have been destroyed by the high temperatures associated with the eruption of the younger Tertiary volcanic rocks. The potential for oil and gas in the underlying sediments is therefore uncertain. Springs are abundant in the study area and range in temperature from 64° to 70°F. The resource potential for geothermal energy is low.

INTRODUCTION

The White Rock Range Wilderness Study Area (NV-040-202/UT-040-216) occupies 23,625 acres in Lincoln County, Nevada, and Beaver and Iron Counties, Utah, along the southern Nevada-Utah state line (fig. 1). Extending across the crest of the north-trending White Rock Mountains, the study area lies between Camp Valley Creek on the west and Hamlin Valley Wash on the east (fig. 1). Streams flow to the west and east from the central mountainous part of the study area and drain into large alluvial fans. Numerous springs are also present. Elevations range from a low of 6,520 ft on the eastern border of the study area to 9,069 ft in the northern part of the study area. White Rock Peak, elevation 9,146 ft, the highest peak in the White Rock Mountains, is just to the north of the study area. The study area is characterized by steep, rocky terrain covered by pinyon and juniper bushes; the amount of outcrop is severely limited in the more densely vegetated areas.

Ursine, the town nearest to the study area, is about 15 mi southwest. The larger town of Pioche is about 30 mi southwest of the study area along Nevada Highway 322. Access to the study area is by four-wheel-drive unimproved roads which approach the study area from the eastern and western sides; these roads are passable during the drier months of the year. A few roads extend into the study area at the southern and southeastern sides. Game trails cross the study area but are commonly obscured in the more heavily vegetated areas.

A mineral resource assessment of the study area by the U.S. Geological Survey in May 1984 consisted of reconnaissance geologic mapping at scale 1:24,000, combined with stream-sediment and rock sampling and subsequent analyses of the samples. Detailed geologic mapping of the study area was done in June 1985, along with a more thorough examination of areas which yielded chemical anomalies in the previous year's study. Aerial photographs were used extensively to supplement geologic mapping and to determine regional structures. Thin sections of representative rock samples were obtained for more detailed petrologic studies. Crystal-rich rocks were point counted to determine the relative percentages of the phenocryst phases and to help identify the various tuff units. Geophysical studies were done in July 1985.

Prior to the field investigation of the wilderness study area, U.S. Bureau of Mines personnel reviewed pertinent published and unpublished literature. Files at the U.S. Bureau of Land Management state offices in Reno, Nev., and Salt Lake City, Utah, were reviewed for mining-claim locations and oil and gas and geothermal leases and lease applications. Lessees, mine owners, and persons having knowledge of mineral occurrences and mining activities near or within the study area were contacted.

U.S. Bureau of Mines field studies in June 1984 included surveying, mapping, and sampling known prospects and mineralized areas in and within 1 mi of the wilderness study area. Several traverses were made within the study area in areas of known faulting. An aerial reconnaissance of the study area was made by helicopter to search for indications of mining activity and mineralization. The results of this study were reported in detail by Gese (1985).

Bureau of Mines personnel collected 15 chip, grab, and select samples. All samples were fire assayed for gold and silver and analyzed by semiquantitative optical-emission spectrographic methods for 40 elements. Results of the analyses were summarized by Gese (1985). Complete analytical results for all samples are available for public inspection at the Bureau of Mines Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO 80225.

Acknowledgments.—We acknowledge personnel in the Bureau of Land Management office in Ely, Nev., for their assistance and cooperation. Discussions with M. G. Best (Brigham Young University) about the stratigraphy of the rocks of the White Rock Mountains were extremely helpful. R. P. Dickerson and D. S. Hovorka of the U.S. Geological Survey assisted in geologic mapping. The geologic map of Ekren and others (1977) provided information concerning the regional geology in Nevada. The mineral resource potential of the wilderness study area was classified according to the system of Goudarzi (1984) (see inside cover).

APPRAISAL OF IDENTIFIED RESOURCES

By Diann D. Gese, U.S. Bureau of Mines

Mining and Mineral-Exploration History

As of July 1984, no mining activity had taken place within the study area, and neither lode nor placer-mining claims were present. About 1 mi southeast of the study area, in Iron County, Utah, gold and silver were being mined from large shear zones in the volcanic rocks and recovered at a small cyanide heap-leach operation. This operation, known as the Bargain mine, is in sec. 14, T. 31 S., R. 20 W., on the East Summit mining claims (fig. 2).

Oil and gas leases cover part of the eastern side of the study area, mostly within Beaver County, Utah. Pliocene or Pleistocene lake beds, favorable strata for hydrocarbon accumulations, are directly east of the study area in Hamlin Valley (Tschanz and Pampeyan, 1970). No field evidence of any geophysical surveys was found and no test wells have been drilled for oil and gas within or near the study area.

Mining Districts and Mineral Occurrences

The White Rock Range Wilderness Study Area is about 8 mi northwest of the Stateline mining district (fig. 1). Mineral deposits in this district are gold- and silver-bearing fissure veins in silicified, red-stained, altered rhyolite or andesite (Tschanz and Pampeyan, 1970; Thomson and Perry, 1975).

Several northwest-trending, nearly vertical breccia veins in the andesite of the Tertiary Isom Formation (M. I. Toth, oral commun., 1985) have been explored by means of three pits, one trench, and three adits (now caved) about 500 ft east of the study area in sec. 8, T. 3 N., R. 71 E. (fig. 3). The veins occur along faults and consist of rhyolite breccia, limonite, hematite, clay, pyrite, and manganese oxides in a quartz matrix. Quartz also occurs as boxwork structures on the surface of the veins. The boxes are rhombohedral and may indicate the replacement of a carbonate mineral. Most pyrite grains visible in hand specimen and polished section have been partly oxidized to hematite. Feldspar phenocrysts in the rhyolite breccia have been altered to clay. Manganese oxides and hematite form veinlets throughout the vein. Judged by the size of the dumps at the adits, the underground workings probably are not extensive; they are not known to extend into the study area.

Fifteen samples were taken by Bureau of Mines personnel from surface exposures of the veins and from the dumps of the workings (fig. 3). Thirteen samples contained from a trace to 0.10 oz gold/ton; five contained from 0.1 to 0.2 oz silver/ton. As much as 0.3 percent barium was present in all samples, and one sample contained 200 ppm zinc (Gese, 1985). No mineralized veins were found within the study area boundaries; however, similar country rock and faulting do occur there.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Margo I. Toth, Rebecca G. Stoneman, and H. Richard Blank, Jr., U.S. Geological Survey

Geology

Geologic Setting

The geology of the region directly east of the White Rock Range Wilderness Study Area in Utah is described in detail by Best and Grant (in press), Best and others (in press), and Rowley and others (1979) and can be related to the study area. Widespread silicic volcanic rocks of Oligocene age (33 to 28 Ma, Mega-annum) are present within and in the vicinity of the wilderness study area. The volcanic rocks unconformably overlie eroded remnants of thrust-faulted, warped, and folded Paleozoic and Mesozoic sedimentary rocks, which were deformed during the Late Cretaceous Sevier orogeny. Although some highly silicic volcanic rocks are present, the largest volumes of volcanic rock are dacitic ash-flow tuffs and andesitic lavas. One of the most extensive units erupted during this time is the Needles Range Group, which consists of five units (Best and Grant, in press) and covers much of the study area (pl. 1). Large collapse-type calderas were produced as a result of many of these volcanic eruptions. The northern end of the study area lies along the northeastern edge of the Wilson caldera (Best and Grant, in press).

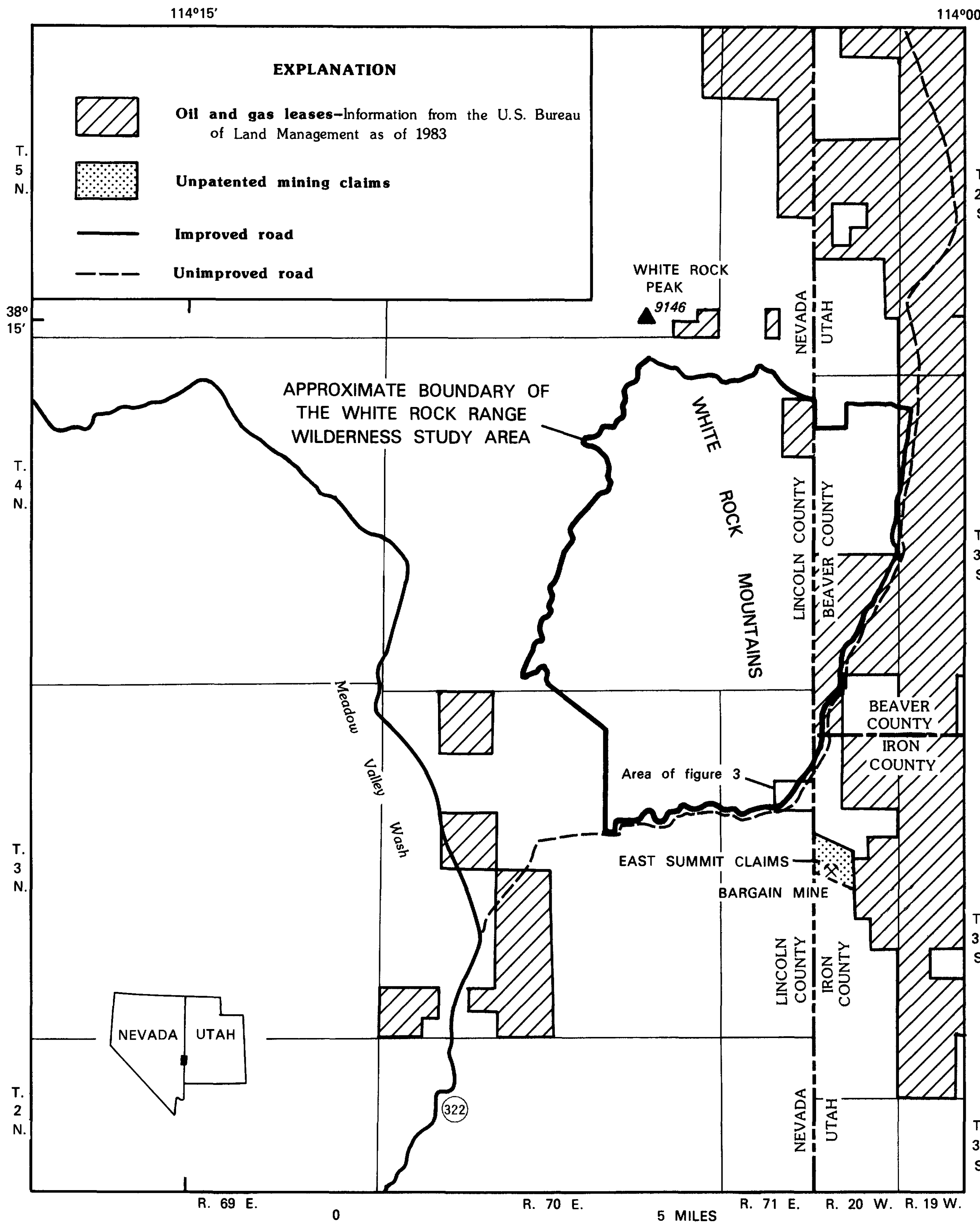


Figure 2. Map showing mining claims and oil and gas leases within and near the White Rock Range Wilderness Study Area, Nevada and Utah.

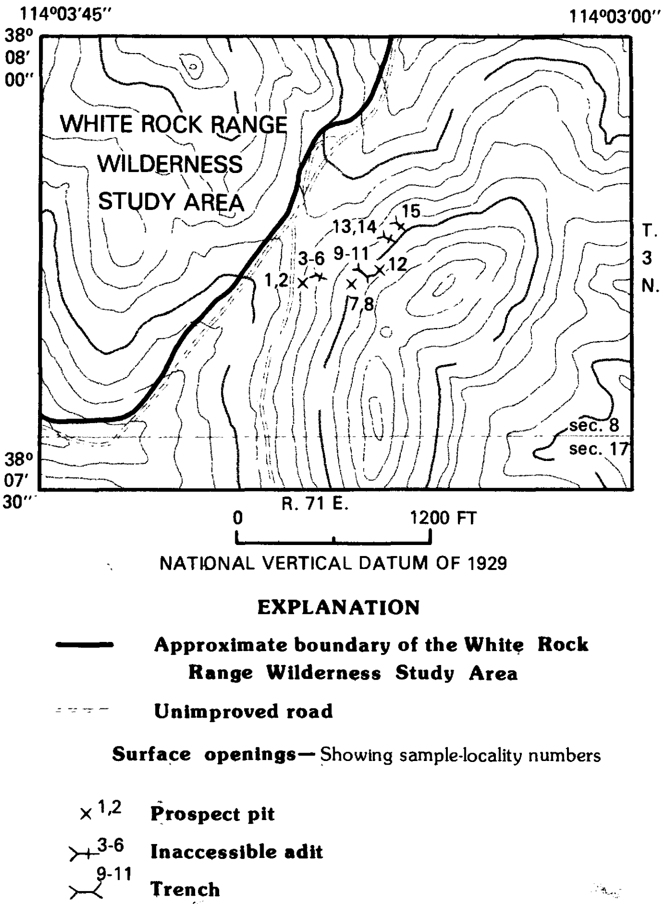


Figure 3. Map showing workings and sample localities at claim adjacent to the White Rock Range Wilderness Study Area, Nevada and Utah. Location of map area shown on figure 2. Base from U.S. Geological Survey, White Rock Peak, scale 1:24,000, 1972. Contour interval, 40 ft.

Several small monzonite-to-granodiorite intrusions associated with the volcanism are scattered throughout western Utah. Several of these were mineralized and have produced copper, lead, zinc, silver, molybdenum, and tin (Lemmon and others, 1973); none of them, however, occur close to the wilderness study area.

The study area lies along the eastern margin of the Basin and Range Province and within the Blue Ribbon lineament of Rowley and others (1978). The lineament is an east-trending zone of Tertiary rhyolite bodies which contain deposits of fluorspar, uranium, and tin. This zone is also unique because it contains abundant northeast- to east-striking high-angle faults, which are oblique to the north-trending normal faults that occur throughout most of the Basin and Range Province.

Southwestern Utah and southeastern Nevada were tectonically inactive during the Oligocene (Best and others, in press), and the deposition of successive ash-flow units progressively smoothed the underlying topography. Basin and Range faulting began about 21 to 22 m.y. ago (Rowley and others, 1978), typified by northeast-trending normal faults resulting from northwest-southeast extension. Some of the northeast-trending faults have vertical displacements as great as 3,200 ft (Best and others, in press). At this time, volcanism in the area changed abruptly to produce the bimodal suite of trachyandesite lavas and high-silica (>75 percent) rhyolites. Although rhyolitic volcanism has continued to the present time, basaltic volcanism has become volumetrically greater through time and has become increasingly concentrated along the margins of the Basin and Range Province (Best and Hamblin, 1978).

Description of Rock Units and Structure

The White Rock Range Wilderness Study Area contains a thick section of Oligocene and Miocene silicic volcanic rocks, flanked on the west by Tertiary lake sediments; extensive colluvial deposits are developed along the western and eastern sides of the range (pl. 1). The volcanic rocks shown as undifferentiated on plate 1 (unit Tt) consist of, from oldest to youngest, the Lund Formation of the Needles Range Group, the tuff of Ripgut Springs, the Isom Formation, the Bauers Tuff Member of the Condor Canyon Formation, and rhyolite tuff and flows of the Blawn Formation. A veneer of andesite (unit Ta) overlies the older volcanic rocks near White Rock Peak.

The Lund Formation (27.9 ± 1 Ma, Best and others, in press) crops out mostly on the western side of the study area and consists of highly indurated, moderately to densely welded tuff, which generally supports only sparse vegetation. It is medium brownish gray to white on fresh surfaces but weathers to a characteristic rusty red. Dense jointing in the unit has resulted in a slablike weathering of the outcrops. Phenocrysts, making up 44 to 54 percent of the rock, consist of plagioclase (28–35 percent), sanidine (0–1.7 percent), quartz (2–5 percent), biotite (2–10 percent), hornblende (2–6 percent), augite (0–2 percent), opaque minerals (1 percent), and trace amounts of sphene and zircon. Pale-green-yellow collapsed pumice fragments make up 0–20 percent of the rock. The Wilson caldera was the source of the Lund Formation.

The tuff of Ripgut Springs, overlying the Lund Formation in sharp contact, consists of bright white to gray-white, nonwelded to partly welded tuff that forms as rounded cliffs and soft slopes. The formation is sparse in the southern part of the study area, and where present it occurs in fault blocks or pinches out. In the northern part of the study area near White Rock Peak, it is as thick as 250 ft. Angular and subrounded pebbles make up 20 percent of the tuff and consist predominantly of red and gray volcanic clasts, many of which were identified as clasts from the Lund and older Wah Wah Springs Formations. Pumice lapilli make up 10 to 40 percent of the tuff; phenocrysts make up no more than 5 to 8 percent of the rock and consist predominantly of plagioclase and minor biotite.

The Isom Formation (261 Ma, Fleck and others, 1975) overlies the tuff of Ripgut Springs in sharp contact and forms well-jointed, rounded towers and cliffs. The basal unit of the Isom consists of a 10-to-15-ft black, strongly welded vitrophyre which contains 5 to 10 percent phenocrysts of euhedral feldspar 1/16 to 1/8 in. (inch) long. In many places the lower parts of the vitrophyre contain 15 to 20 percent inclusions of light-pink, flattened pumice fragments.

Overlying the basal vitrophyre is a reddish-purple, moderately to strongly welded tuff, containing light-gray pumice fragments. Strongly welded samples are characterized by so-called running pumice, where the pumice fragments are so stretched out by welding and flowage that they resemble flow laminae in a rhyolite; some of the fragments extend as far as 10 ft. The pumice layers are locally folded and contorted, especially in the northern part of the study area. Phenocrysts consist of very small (<0.3 in.) euhedral grains of plagioclase and pyroxene, and make up 15 percent of the rock. The Isom is thickest in the northern part of the study area, where it defines the northeastern wall of the Wilson caldera (Best and Grant, in press).

In the southern part of the study area, the Blawn Formation directly overlies the Lund and consists of slightly to moderately welded tuff which commonly forms cliffs. The tuff is generally white to whitish gray and contains 15 to 20 percent phenocrysts of plagioclase, biotite, quartz, and minor sanidine and hornblende. Some of the quartz grains are as large as 1/8 in. across and in places have euhedral terminated crystal faces. The tuff contains 5 to 20 percent pumice fragments and 0 to 25 percent subangular to subrounded rock fragments; many of the rock fragments are from the Lund and Wah Wah Springs Formations. Buff to gray tuffaceous sandstone layers occur in the Blawn and contain some pebble to granule layers.

Rhyolite flows crop out just to the east of the study area, and a small amount of rhyolite flow crops out just within the study area. The flows overlie the Lund and Isom Formations, and although they have not been dated, they probably correlate with the Blawn. The rhyolite is quartz rich and contains 10 to 15 percent phenocrysts of quartz, plagioclase, minor sanidine, and a trace of mafic minerals. The quartz is dark gray, is commonly as large as 1/16 to 1/8 in., and is bipyramidal. Extensive limonite, hematite, and pyrolusite alteration pervades most of the rhyolite outcrops.

Overlying the Blawn Formation, the Bauers Tuff Member of the Condor Canyon Formation crops out in rounded hills and forms rubble-covered slopes. The tuff contains a characteristic black basal vitrophyre as thick as 10 to 15 ft. The vitrophyre contains 15 percent phenocrysts of plagioclase, minor biotite, and 10 to 15 percent flattened pink pumice fragments; the upper part of the vitrophyre contains 10 to 30 percent amygdules, 1 in. across, filled with chalcedony. Overlying the vitrophyre in sharp contact is a slightly to moderately welded, beige to pink tuff with 8 to 10 percent phenocrysts of plagioclase, sanidine, and biotite, and 1 to 20 percent pink pumice fragments.

A veneer of dark-gray andesite (unit Ta, pl. 1) overlies the Isom Formation near White Rock Peak and contains phenocrysts of plagioclase, augite, orthopyroxene, and opaque minerals in an aphanitic groundmass. The age of the andesite is unknown, but based upon correlation with other similar mafic flows, it may be 13 to 12 m.y. old (Best and others, in press).

On the western side of the study area, Pliocene lake sediments of the Panaca Formation (unit Tl, pl. 1) crop out and consist of varicolored flat-lying tuffaceous siltstone, mudstone, and fine-grained sandstone. Dark-gray microcrystalline Cambrian limestone (unit Ꞓs, pl. 1) crops out just to the south of the study area.

Foliation in the welded tuffs is defined by flattened pumice lapilli and strikes mostly to the northeast and dips 20° to 25° to the southeast. Adjacent to faults, the foliation shows highly variable attitudes and may have vertical dips.

Abundant normal faults cross the wilderness study area, but only the more prominent of these faults are shown on plate 1. The faults trend mostly to the northeast, although a few northwest-trending faults are present. Offsets range from a few tens of feet to more than several hundred feet. Most of the springs in the study area occur along faults or at the intersections of faults cutting the base of the pumiceous tuff of Ripgut Springs. None of the faults were observed to cut Quaternary units.

Geochemistry

Methods

The geochemical survey of the wilderness study area included sampling of stream sediments and rocks for chemical analysis. Forty-four samples of stream sediments were collected from stream beds which drained from 1 to 2 square mile areas. Two types of samples were collected at each locality. Panned-concentrate samples were obtained from sediment collected from several different places in the active stream bed where heavy minerals typically accumulate. The sediment was sieved through a stainless-steel screen at the sample site to less than 10 mesh (0.039 in.). Where water was available, the samples were panned to a concentrate of about 0.25 oz (ounce); in dry stream beds, 15 lbs (pounds) of sediment were collected for later panning. A fine-fraction sample was collected from within the active stream channel, commonly along point bars, and consisted of about 0.25 oz of mud, clay, and fine-grained sand. The panned-concentrate sample was collected to analyze for the heavier metallic elements such as copper, lead, zinc, and gold, and the fine fraction of mud and clay was collected to analyze for metals such as molybdenum, uranium, thorium, and arsenic which typically adhere to clay minerals.

Panned-concentrate samples were screened again in the laboratory to 35 mesh (0.0165 in.), and the fraction greater than 35 mesh was discarded. The minus-35-mesh fraction was further processed using bromoform separation and a magnetic separation technique. The heavy, nonmagnetic fraction was split, and one-half of the sample was ground by hand in a mortar and pestle to less than 100 mesh (0.0059 in.) for analysis; the other half of the sample was saved for optical identification of the minerals. Samples were analyzed for 31 elements by semiquantitative emission spectrography, according to the techniques outlined by Grimes and Marranzino (1968). The mud and clay fraction was sieved to minus 100 mesh and analyzed for 31 elements by semiquantitative emission spectrography, and for arsenic, molybdenum, uranium, and thorium, according to the induction-coupled plasma spectroscopy techniques outlined by Taggart and others (1981).

Two types of rock samples were collected from the study area and vicinity. One type consisted of samples from localities containing mineralized or altered rock or having characteristics possibly indicating mineralized rock. In these localities about 0.5 lb of thumb-size rock chips were collected along the outcrop; where mineralized rock was present, the sample was collected along the vein or mineralized layer. At mine dumps, samples were collected of the most mineralized rock. The other type of samples was collected from areas of nonmineralized rock. The various rock units were sampled at random intervals to establish the background values of mineralizing elements and to look for any trends or values that might suggest the presence of mineralized rock. About 0.5 lb of monolithologic, unweathered, thumb-size rock chips were also collected at these localities by sampling along the outcrop for distances of 15 to 20 ft. The sample was collected perpendicular to foliation where evident.

Rock samples were crushed and pulverized to less than 100 mesh and were analyzed by semiquantitative emission spectrography for 31 elements and for arsenic, bismuth, cadmium, antimony, and zinc by flame atomic absorption. Forty-four rock samples were analyzed.

L. A. Bradley, P. H. Briggs, G. W. Day, and R. B. Vaughn of the U.S. Geological Survey performed the analyses.

Results

Panned-concentrate samples from the wilderness study area showed detectable concentrations of Ba, Co, Cr, Cu, La, Mo, Nb, Pb, Sc, Sn, Sr, V, Y, and Zr. Of these elements, molybdenum, lead, copper, and tin are common indicators of base-metal mineralization. Molybdenum was present in four samples (detection limit 10 ppm); two samples contained 10 ppm (WJS007 and WJS010, pl. 1) and two samples contained 15 ppm (WJS011 and WJS016, pl. 1). These anomalous samples were collected from the southwestern margin of the study area, which is predominantly underlain by the Lund Formation of the Needles Range Group, possibly the source for the molybdenum. However, some of the stream drainages also expose small parts of the Isom Formation, Blawn Formation, and the Bauers Tuff Member of the Condor Canyon Formation.

Lead, ranging from 20 to 500 ppm, was detected in eight samples. Samples with the highest concentrations of lead were collected from the northeastern part of the study area. Galena was identified in a panned-concentrate sample containing 500 ppm lead and was the likely source for the high lead content. Copper ranged from 10 to 20 ppm in 21 samples and showed no particular geographic distribution.

Tin was detected in 28 samples and had quantifiable concentrations in 21 samples, ranging from 20 to 1,000 ppm. Samples with the highest concentrations of tin were from the northeastern part of the study area (WMT037, 038, 039, pl. 1), which is underlain by the Isom Formation and the tuff of Ripgut Springs. Therefore, the source of the tin in these samples may have been these formations. Cassiterite (wood tin?) was identified in the panned-concentrate samples. Tin anomalies were not detected in any rock samples, so it is unlikely that the cassiterite is concentrated in veins or faults; more probably, it is dispersed in the rocks, possibly as vug fillings or in microfractures.

The fine fraction (<100 mesh) of the mud and clay samples contained from 6.0 to 22.7 ppm thorium and 3.12 to 9.93 ppm uranium. Arsenic (detection limit 10 ppm) was detected in one sample (WMT008), which contained 20 ppm. None of the fine-fraction samples contained detectable molybdenum (detection limit 2 ppm). None of these concentrations was considered to be anomalous.

A hydrogeochemical survey of the White Rock Mountains and Wilson Creek Range by McHugh and others (1983) revealed no anomalous concentrations of trace elements in spring water from the study area. Water temperatures from three springs in the study area ranged from 64° to 70°F.

Of the 44 rock samples collected at random from the different formations in the study area, only three samples showed anomalous concentrations of elements commonly associated with mineralization. Sample WMT041 contained 5 ppm molybdenum, and samples WMT043 and WJS025 contained 7 ppm molybdenum. These rock samples, collected from the Isom Formation in the northeastern part of the study area, are from the same area which had high tin and lead concentrations in panned-concentrate samples. Two samples from a prospect pit 500 ft southeast of the study area at Reed's Cabin Summit (WMT034 and WMT035, pl. 1) in the Isom Formation contained 5 and 7 ppm silver, respectively, and sample WMT034 contained 3 ppm beryllium. The mineralized rock does not extend into the study area.

Geophysics

Data Base

Reconnaissance geophysical data are seldom employed for the direct detection of mineral deposits but are useful in establishing a three-dimensional geologic framework that serves to guide exploration. The geophysical data base for the White Rock Range Wilderness Study Area consists of results from spectral aeroradiometric surveys, aeromagnetic surveys, and regional gravity surveys. Aeroradiometric data were obtained as part of the NURE (National Uranium Resource Evaluation) program. They were evaluated by J. S. Duval of the U.S. Geological Survey, who noted the presence of "moderate" overall radioactivity for the rocks in the wilderness study area (written commun., 1985), with average values of 2.5–3.0 percent potassium, 20–35 ppm equivalent uranium, and 10–15 ppm equivalent thorium. The NURE traverses were flown eastwest at a nominal 400 ft above ground and 3-mi spacing. Aeromagnetic data were also recorded on the NURE flights, but more thorough aeromagnetic coverage of the study area is provided by a regional survey of the southeastern part of the Lund $1^\circ \times 2^\circ$ quadrangle (U.S. Geological Survey, 1973) (fig. 4). Six flight lines of this survey traverse the study area. The lines were flown north-south, 1 mi apart, at a barometric elevation of 9,000 ft using a proton magnetometer. As the highest peaks of the White Rock Mountains slightly exceed 9,000 ft in elevation and the flanking valleys are as low as 6,000 ft, variations in relief are a significant factor in interpretation. Gravity data for the study area (fig. 5) were obtained from regional Bouguer gravity anomaly maps of the Lund and Richfield $1^\circ \times 2^\circ$ quadrangles (Snyder and others, 1984; Cook and others, 1981), augmented by 16 additional gravity stations established during June 1985 (H. R. Blank, Jr., unpub. data). No other geophysical data for the wilderness study area are known to the authors.

Magnetics

Most of the wilderness study area has a prominent positive anomaly with several superimposed local maxima (fig. 4). This anomaly results from strongly magnetized volcanic rocks of the White Rock Mountains, which crop out within a few hundred feet of the magnetometer; the steep gradient on the western side of the anomaly coincides with a range-front fault. Vitrophyric zones of ash-flow tuffs, andesite flows, and hypabyssal intrusions are all plausible sources within the volcanic pile. The pronounced northwestern orientation of the anomalies, transverse to topographic grain, suggests fault control of the location of the sources.

Two additional highs are west of the wilderness study area (fig. 4), one near the center of Spring Valley and the other near its northern margin. Their sources are probably volcanic rocks (extrusive or hypabyssal intrusive) concealed beneath late Tertiary and Quaternary valley-fill deposits but contiguous with rocks exposed in the adjacent ranges. The lower amplitude and smoother character of these anomalies with respect to the White Rock Mountains anomaly most likely result from the greater distance between source and level of observation, because the survey was at a constant barometric elevation.

The two Spring Valley highs and the White Rock Mountains high lie across a broad, somewhat irregular but predominantly east-trending aeromagnetic ridge extending for nearly 180 mi from eastern Nevada to central Utah (see colored aeromagnetic maps of Nevada and Utah by Zietz and others, 1976; 1978). The significance of this ridge has been discussed by Stewart and others (1977) and Zietz and others (1977). In their view, it is the expression of a deep crustal fracture system which has been a locus of volcanism, hypabyssal intrusion, and hydrothermal activity at least since the mid-Tertiary. It encompasses the east-trending Pioche mineral belt of Roberts (1964, 1966) in Nevada and the Wah Wah-Tushar mineral belt of Hilpert and Roberts (1964), and it also includes most of the east-northeast-trending Pioche mineral belt as redefined by Shawe and Stewart (1976). Thus, the aeromagnetic ridge is associated with many important ore deposits.

The steep east-trending anomaly gradient at the southern terminus of the Spring Valley and White Rock Mountains highs marks the southern margin of the Blue Ribbon lineament (Rowley and others, 1978), a structural zone about 15 mi wide wholly within the area of the aeromagnetic ridge. This gradient probably represents a concealed fracture. It intersects the White Rock Mountains at about right angles to the range front, and hence to basin-and-range structure. South of the gradient, the absolute total-intensity datum is lower and the anomaly relief is relatively subdued, which precludes the existence of significant thicknesses of strongly magnetized sources at or near the surface. Volcanic rocks that crop out in the southern part of the White Rock Mountains are probably a veneer on carbonate rocks rather than intruded into them.

Gravity

Figure 5 is a complete Bouguer gravity anomaly map covering the same area as in figure 4. In general, the gravity

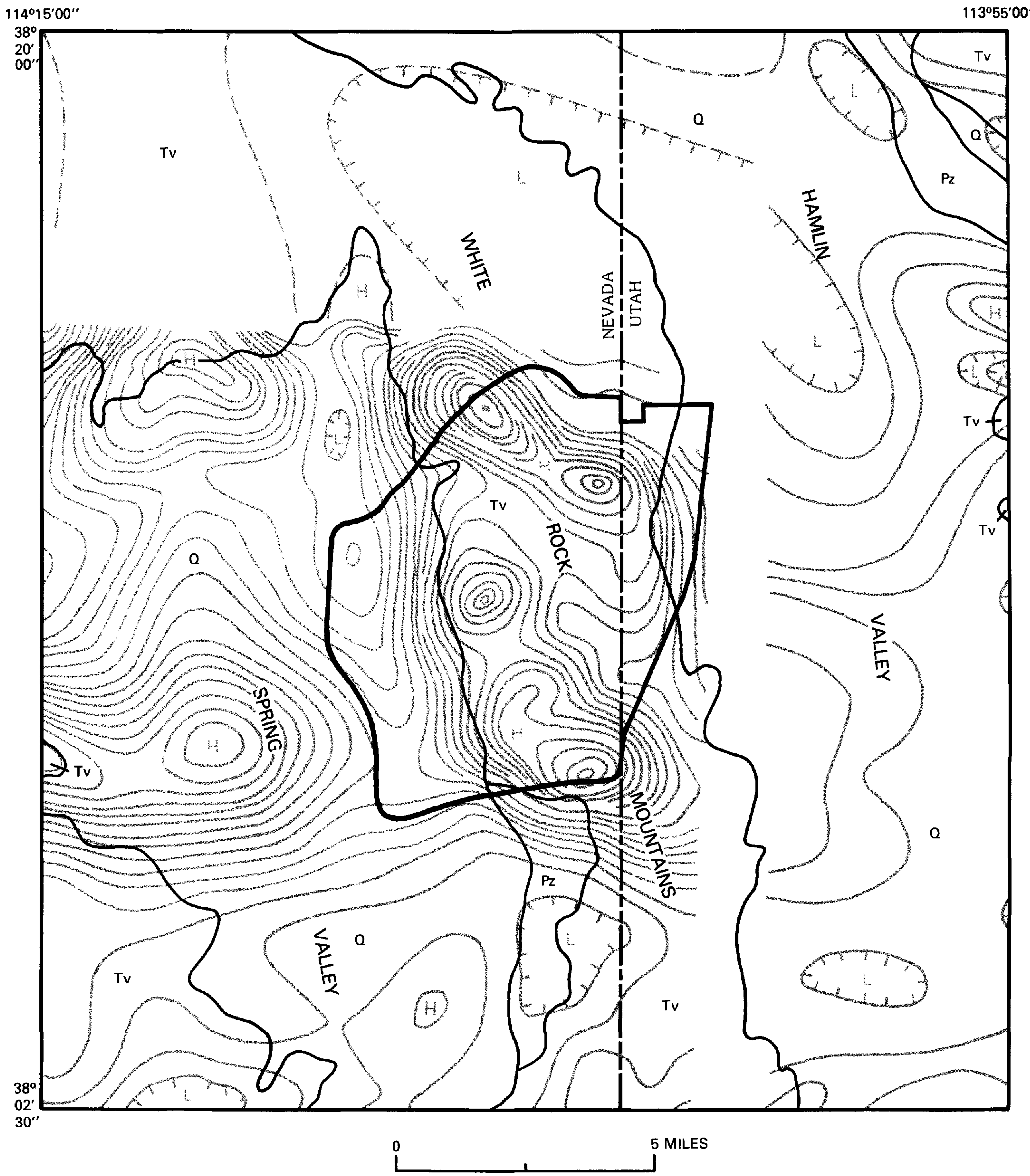


Figure 4 (above and facing page). Residual total-intensity aeromagnetic map of the White Rock Range Wilderness Study Area, Nevada and Utah. Composited from parts of the aeromagnetic map of the Lund quadrangle (U.S. Geological Survey, 1973) and two additional surveys. North of lat 38°15′ N., the source of data is an aeromagnetic map of east-central Nevada (U.S. Geological Survey, 1978) at 20-nT contour interval. Traverses were flown east-west at 12,000 ft and 4-mi spacing. East of long 114° W., source is an aeromagnetic map of parts of the Richfield 1°×2° quadrangle, Utah (U.S. Geological Survey, 1972), at contour interval 100 nT. Traverses were flown north-south at 9,200 ft and 2-mi spacing. The International Geomagnetic Reference Field has been removed from all three data sets, and the datum for the residual field in each case is arbitrary.

EXPLANATION

	Magnetic contours– Showing residual total-intensity magnetic field of Earth in nanoteslas (nT). Contour interval 20 nT in western part of map area, 100 nT in eastern part, and 50 nT in northwestern and southwestern parts. Hachures indicate closed areas of lower magnetic intensity. Datum is arbitrary
	Magnetic high
	Magnetic low
	Generalized geologic contact
Q	**Quaternary surficial deposits and late Tertiary lake beds**
Tv	**Tertiary volcanic rocks**
Pz	**Paleozoic sedimentary rocks**
	Approximate boundary of the White Rock Range Wilderness Study Area

anomaly variations shown on figure 5 are produced by structural relief on the surface of Paleozoic and older rocks, which are mostly buried beneath lighter surficial deposits and Tertiary volcanic rocks, and to a lesser extent by density contrasts within the volcanic pile. A poorly defined saddle on a roughly north-trending, elongate gravity high or ridge which closely follows the topography of the White Rock Mountains is centered on the wilderness study area. The highest Bouguer gravity levels on this ridge are just south of the wilderness study area over outcrops of Paleozoic carbonate rocks. Bouguer maxima near the southwestern and northeastern corners of the area of figure 5 are also associated with exposures of Paleozoic strata.

The two lows west of the saddle are disposed on either side of the magnetic high in the middle of Spring Valley and may reflect thick accumulations of valley fill interrupted by a buried volcanic edifice. The southern boundary of these lows approximately coincides with the east-trending aeromagnetic gradient marginal to the Blue Ribbon lineament. The interpreted east-west structure is probably volcano-tectonic in origin. A gravity high just north of the two lows may be due to a Paleozoic basement high, as it occurs between two magnetic maxima, and its source is probably nonmagnetic.

An extensive linear gravity low to the east of the White Rock Mountains delimits the thickest fill of Hamlin Valley. The steep northern termination of the low, transverse to the valley axis, near the northeastern corner of the wilderness study area, suggests the presence of a concealed bedrock step in the valley floor. The step appears to be oriented northeast and is possibly contiguous with a structure that transects the White Rock Mountains through the gravity saddle in the wilderness study area. Its tectonic significance is unknown.

The northwest-trending steep gravity gradient in the northeastern corner of the area of figure 5 (the eastern flank of the Hamlin Valley low) forms part of the perimeter of a very broad (30 × 18 mi) elliptical gravity depression, elongate to the northwest. This depression encompasses the entire area of figure 5 and is associated with the Indian Peak and Wilson Creek calderas.

Mineral and Energy Resources

The White Rock Range Wilderness Study Area has low mineral resource potential for deposits containing metals, with certainty level B. Although geophysical data suggest that the study area should be regarded as favorable for metallic mineral deposits, no mineralized areas were identified. Local anomalous concentrations of tin, lead, and molybdenum are in the rocks and panned-concentrate samples from the northeastern part of the study area, but no mineralized rock was observed in outcrop. These anomalous samples are from along the northeastern margin of the Wilson caldera; caldera structures have been shown to have fractures that guide later hydrothermal activity (Steven and Lipman, 1976). The source of the anomalies may have been an underlying hypabyssal intrusion, as suggested by geophysical data.

.A small area of gold- and silver-mineralized rock occurs 500 ft southeast of the wilderness study area at Reed's Cabin Summit in sheared and partly brecciated tuff of the Isom Formation. Mineralization may have been related to an underlying hypabyssal intrusion. The sharp contact of the Isom Formation with the adjacent Paleozoic rock may have been a conduit for mineralizing fluids. Several faults also intersect in the area of mineralized rock and would also have been conduits for hydrothermal fluids. This mineralized rock is similar to other gold-silver deposits in the Stateline district to the south of the study area (Tschanz and Pampeyan, 1970). The mineralized rock, however, does not extend into the study area.

The wilderness study area lacks host rocks and structures favorable for the occurrence of oil, gas, or coal. The mineral resource potential for these commodities is therefore low, with certainty level C. The study area may be underlain by Paleozoic sedimentary rock, but without extensive geophysical exploration, the depth to the sedimentary rock is unknown. Any hydrocarbons associated with these rocks could have been destroyed by the high temperatures associated with the eruption of the Tertiary volcanic rocks. The presence of underlying oil and gas- or coal-bearing rock is therefore uncertain.

Although there are abundant springs in the study area, none of them contain warm or hot water; temperatures range from 64° to 70°F. The potential for geothermal energy in the wilderness study area is therefore low, with certainty level B.

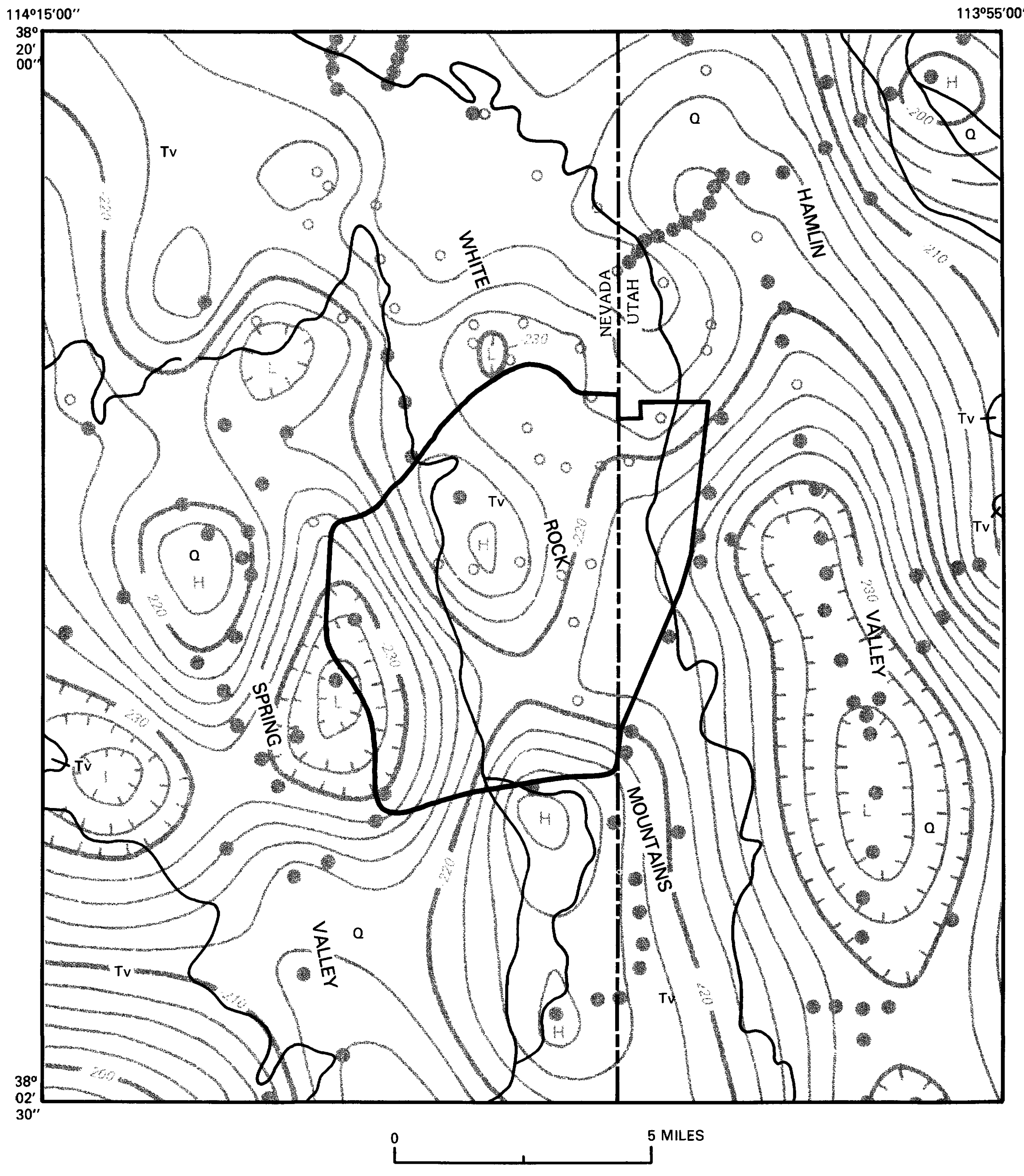


Figure 5 (above and facing page). Complete Bouguer gravity anomaly map of the White Rock Range Wilderness Study Area, Nevada and Utah. Gravity compiled at a reduction density of 2.67 g/cm^3. Observed gravity at each station reduced by standard procedures (Cordell and others, 1982). Terrain corrections applied to a radius of 100 mi.

EXPLANATION

— 20 —	**Complete Bouguer gravity contour**–Contour interval, 2 milligals. Hachures indicate closed areas of lower gravity
H	**Gravity high**
	Gravity low
●	**Gravity station** –from R. W. Saltus, written commun., 1985, and Cook and others, 1981
○	**Gravity station**–This study
———	**Generalized geologic contact**
Q	**Quaternary surficial deposits and late Tertiary lake beds**
Tv	**Tertiary volcanic rocks**
Pz	**Paleozoic sedimentary rocks**
━━━	**Approximate boundary of the White Rock Range Wilderness Study Area**

REFERENCES CITED

Best, M. G., and Grant, S. K., in press, Stratigraphy of the volcanic Oligocene Needles Range Group in southwestern Utah: U.S. Geological Survey Professional Paper 1433-A.

Best, M. G., and Hamblin, W. K., 1978, Origin of the northern Basin and Range province—implications from the geology of its eastern boundary, *in* Smith, R. B., and Eaton, G. P., eds., Cenozoic tectonics and regional geophysics of the western Cordillera: Geological Society of America Memoir 152, p. 313-340.

Best, M. G., Mehnert, H. H., Keith, J. D., and Naeser, C. W., in press, Miocene magmatism and tectonism in and near the southern Wah Wah Mountains, southwestern Utah: U.S. Geological Survey Professional Paper 1433-B.

Cook, K. L., Adhidjaja, J. I., and Gabbert, S. C., 1981, Complete Bouguer gravity anomaly and generalized geology map of Richfield 1°×2° quadrangle, Utah: Utah Geological and Mineral Survey Map 59, scale 1:250,000.

Cordell, Lindrith, Geller, G. R., and Hildenbrand, T. G., 1982, Complete Bouguer gravity anomaly map of the Rio Grande rift, Colorado, New Mexico, and Texas: U.S. Geological Survey Geophysical Investigations Map GP-949, scale 1:1,000,000.

Ekren, E. B., Orkild, P. P., Sargent, K. A., and Dixon, G. L., 1977 [1978], Geologic map of the Tertiary rocks, Lincoln County, Nevada: U.S. Geological Survey Miscellaneous Investigations Map I-1041, scale 1:250,000.

Fleck, R. J., Anderson, J. J., and Rowley, P. D., 1975, Chronology of mid-Tertiary volcanism in the High Plateaus region of Utah: Geological Society of America Special Paper 160, p. 53-61.

Gese, D. D., 1985, Mineral resources of the White Rock Range Wilderness Study Area (NV-040-202), Lincoln County, Nevada, and Beaver and Iron Counties, Utah: U.S. Bureau of Mines Open-File Report MLA 31-85, 14 p.

Goudarzi, G. H., 1984, compiler, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84-787, 42 p.

Grimes, D. J., and Marranzino, A. P., 1968, Direct-current arc and alternating current spark emission spectrographic field methods for the semiquantitative analyses of geologic materials: U.S. Geological Survey Circular 591, 6 p.

Hilpert, L. S., and Roberts, R. J., 1964, Geology—Economic geology, *in* Mineral and water resources of Utah: U.S. Congress, 88th, 2d Session, Committee Print, p. 28-34.

Lemmon, D. M., Silberman, M. L., and Kistler, R. W., 1973, Some K-Ar ages of extrusive and intrusive rocks of the San Francisco and Wah Wah Mountains, Utah: Utah Geological Association Publication 3, p. 23-26.

McHugh, J. B., Miller, W. R., and Ficklin, W. H., 1983, A hydrogeochemical survey in east-central Nevada: U.S. Geological Survey Open-File Report 83-286, 28 p.

Roberts, R. J., 1964, Economic geology, *in* Mineral and water resources of Nevada: U.S. Congress, 88th, 2d Session, Senate Document 87, p. 39-48.

______1966, Metallogenic provinces and mineral belts in Nevada, *in* American Institute of Mining, Metallurgical, and Petroleum Engineers, Pacific Southwest Mineral Industry Conference, Sparks, Nev., 1965, Papers, Pt. A: Nevada Bureau of Mines and Geology Report 13, Pt. A, p. 47-72.

Rowley, P. D., Lipman, P. W., Mehnert, H. H., Lindsey, D. A., and Anderson, J. J., 1978, Blue Ribbon lineament, an east-trending structural zone within the Pioche mineral belt of southwestern Utah and eastern Nevada: U.S. Geological Survey Journal of Research, v. 6, p. 175-192.

Rowley, P. D., Steven, T. A., Anderson, J. J., and Cunningham, C. G., 1979, Cenozoic stratigraphic and structural framework of southwestern Utah: U.S. Geological Survey Professional Paper 1149, 22 p.

Shawe, D. R., and Stewart, J. H., 1976, Ore deposits as related to tectonics and magmatism, Nevada and Utah: American Institute of Mining, Metallurgical, and Petroleum Engineers Transactions, v. 260, p. 225-232.

Snyder, D. B., Healey, D. L., and Saltus, R. W., 1984, Bouguer gravity map of Nevada—Lund Sheet: Nevada Bureau of Mines and Geology Map 80, scale 1:250,000.

Steven, T. A., and Lipman, P. W., 1976, Calderas of the San Juan volcanic field, southwestern Colorado: U.S. Geological Survey Professional Paper 958, 35 p.

Stewart, J. H., Moore, W. J., and Zietz, Isidore, 1977, East-west patterns of Cenozoic igneous rocks, aeromagnetic anomalies, and mineral deposits, Nevada and Utah: Geological Society of America Bulletin, v. 88, no. 1, p. 67-77.

Taggart, J. E., Lichte, F. E., and Wahlberg, J. S., 1981, Methods of analysis of samples using X-ray fluorescence and induction-coupled plasma spectroscopy, *in* Lipman, P. W., and Mullineaux, D. R., eds., The 1980 eruptions of Mount St. Helens, Washington: U.S. Geological Survey Professional Paper 1250, p. 683-687.

Thomson, K. C., and Perry, L. I., 1975, Reconnaissance study of the Stateline mining district, Iron County, Utah: Utah Geology, v. 2, no. 1, p. 27-47.

Tschanz, C. M., and Pampeyan, E. H., 1970, Geology and mineral deposits of Lincoln County, Nevada: Nevada Bureau of Mines Bulletin 73, 188 p.

U.S. Geological Survey, 1972, Aeromagnetic map of the Richfield and Cedar City 1°×2° quadrangles, Utah: U.S. Geological Survey Open-File Report 72-387, scale 1:250,000.

———1973, Aeromagnetic map of the southeastern part of the Lund and the eastern half of the Caliente 1°×2° quadrangles, Nevada: U.S. Geological Survey Open-File Report 73-298, scale 1:250,000.

———1978, Aeromagnetic map of east-central Nevada: U.S. Geological Survey Open-File Report 78-281, scale 1:250,000.

Zietz, Isidore, Gilbert, F. P., and Kirby, J. R., 1978, Aeromagnetic map of Nevada—Color coded intensities: U.S. Geological Survey Geophysical Investigations Map GP-922, scale 1:1,000,000.

Zietz, Isidore, Shuey, Ralph, and Kirby, J. R., Jr., 1976, Aeromagnetic map of Utah: U.S. Geological Survey Geophysical Investigations Map GP-907, scale 1:1,000,000.

Zietz, Isidore, Stewart, J. H., Gilbert, F. P., and Kirby, J. R., 1977, Aeromagnetic map of Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-902, scale 1:500,000.

GEOLOGIC TIME CHART

Terms and boundary ages used by the U. S. Geological Survey, 1986

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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