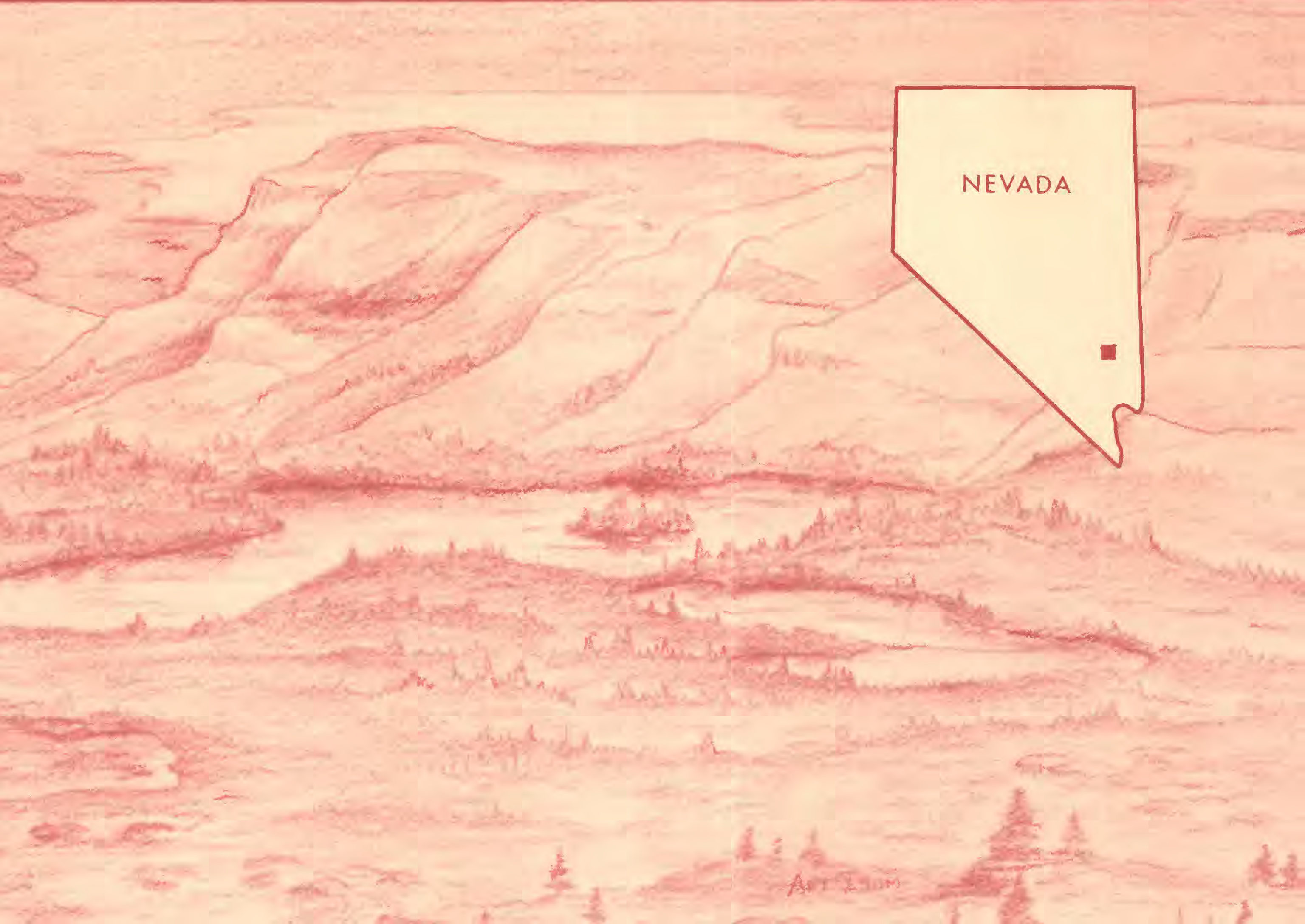
Mineral Resources of the Mormon Mountains Wilderness Study Area, Lincoln County, Nevada

U.S. GEOLOGICAL SURVEY BULLETIN 1729–B



Chapter B

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U.S. GEOLOGICAL SURVEY BULLETIN 1729

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
SOUTHEASTERN NEVADA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Mormon Mountains (NV–050–161) Wilderness Study Area, Lincoln County, Nevada.

CONTENTS

PLATE

[Plate is in pocket]

FIGURES

TABLE

Mineral Resources of the Mormon Mountains Wilderness Study Area, Lincoln County, Nevada

By Daniel R. Shawe, H. Richard Blank, Jr., Brian P. Wernicke[1], Gary J. Axen[2], Harlan N. Barton, *and* Gordon W. Day
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ABSTRACT

The USBM (U.S. Bureau of Mines) and the USGS (U.S. Geological Survey) studied the identified mineral resources (known) and the mineral resource potential (undiscovered) of the Mormon Mountains Wilderness Study Area (NV–050–161), Nevada. The Mormon Mountains Wilderness Study Area contains no identified resources; occurrences of commercial-grade limestone of undetermined extent and minor deposits of sand and gravel are present. The study area has high mineral resource potential for (1) copper, lead, zinc, silver, and (or) gold in its southern part and (2) copper, lead, zinc, silver, gold, arsenic, and (or) antimony in its northern part (fig. 1). Part of the study area has moderate mineral resource potential for antimony. Two areas in the central part of the study area have moderate mineral resource potential for tungsten, molybdenum, and (or) tin. The remainder of the study area has low mineral resource potential for all metals. The study area has moderate energy resource potential for oil and gas, except for areas of low potential where significant hydrothermal activity has occurred. It has low mineral and energy resource potential for manganese, barite, vermiculite, coal, and geothermal energy.

SUMMARY

That part of the Mormon Mountains Wilderness Study Area (23,690 acres) on which mineral surveys were conducted is in the core of the Mormon Mountains, in southeastern Lincoln County, Nev., 60 mi (miles) northeast of Las Vegas (fig. 2). It is accessible by poor jeep roads from Meadow Valley Wash on the west side and from the Carp–Mormon Mesa road on the east side. The study area ranges in altitude from about 3,440 ft (feet) at its western boundary to 7,414 ft at Mormon Peak.

The study area is near the south end of the Nevada-Utah section of the Basin-range tectonic province. The Mormon Mountains form a domelike structure, the core of which is ancient Precambrian crystalline rocks (see geologic time chart in Appendix) that are exposed in small patches at the west edge of the study area and just south of the study area. Doming of the mountains probably was a result of intrusion of igneous rocks sometime in Mesozoic-Tertiary time. Cambrian clastic marine sedimentary rocks lie in depositional contact upon the crystalline rocks. A series of low-angle faults has episodically moved a thick section of Paleozoic marine sedimentary rocks, mostly carbonate strata, onto the older rocks. Tertiary volcanic rocks, in part also emplaced on low-angle faults, occur along the north margin of the study area. Younger high-angle faults of diverse orientations offset the low-angle faults and the rock formations.

The Whitmore mine, 1.3 mi south of the south end of the study area (fig. 1), produced a small amount of copper. The Iron Blossom prospect, within 0.2 mi north of the north margin of the study area, was probably developed for gold or silver. The study area has occurrences of commercial-grade limestone and minor deposits of sand and gravel; however, neither of these is classified as an identified resource.

The Mormon Mountains Wilderness Study Area has high mineral resource potential for (1) copper, lead, zinc, silver, and (or) gold in its southern part and (2) copper, lead, zinc, silver, gold, arsenic, and (or) antimony in its northern part (fig. 1). Areas of high potential are defined by metal-

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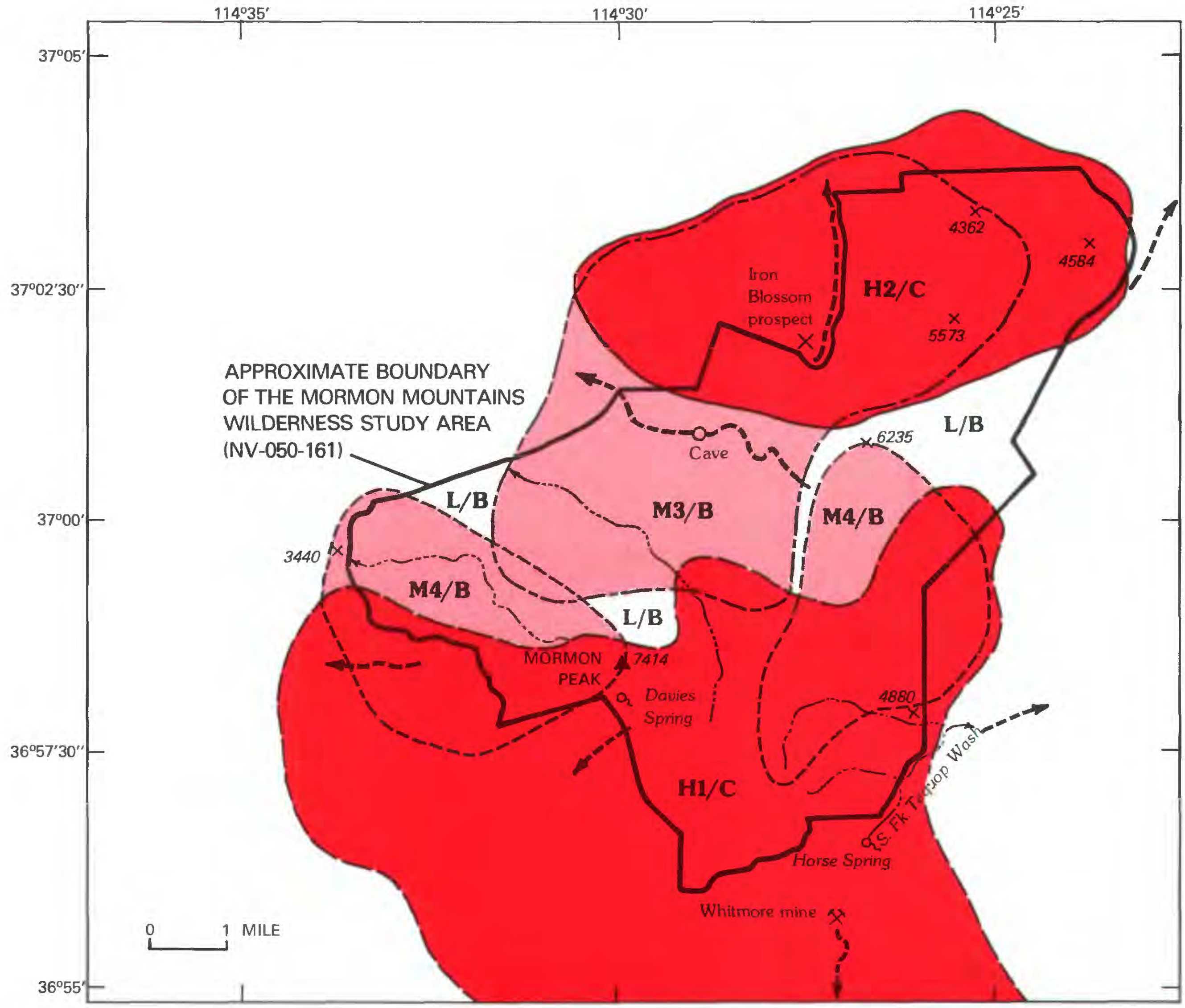


Figure 1 (above and facing page). Summary map showing mineral resource potential and mine and prospect locations in the Mormon Mountains Wilderness Study Area and vicinity, Nevada.

mineralized zones in shears and breccias along faults, by anomalously high metal concentrations in stream sediments, by favorable host formations that are cut by abundant faults and fractures, and by inferred centers of igneous intrusion. Metals were deposited in extensive hydrothermal systems that circulated metal-bearing fluids through faults and fractures. Hydrothermal fluids had their sources in the postulated igneous intrusive rocks at depth, or they consisted of ground waters heated by the igneous intrusions.

Part of the study area has moderate mineral resource potential for antimony (fig. 1). Two areas in the central part of the study area have moderate mineral resource potential for tungsten, molybdenum, and (or) tin (fig. 1). Areas of moderate potential are defined by evidence similar to that used to define areas of high potential, but the evidence is not as extensive nor as firmly established. Mineral resource potential for all metals in the remainder of the study area is low, based on minimal evidence for their occurrence and lack of favorable geologic environment. The Mormon Mountains Wilderness Study Area has a moderate energy resource potential for oil and gas based on presence of suitable source rocks, maturation history, reservoir rocks, and structural and stratigraphic traps, except for areas of low potential where significant hydrothermal activity has occurred.

The study area has low mineral resource potential for manganese, barite, and vermiculite. Deposits of these commodities exist near the study area, but evidence is minimal for their occurrence within the study area. The geologic environment of the study area is not favorable for the occurrence of geothermal and coal resources. Therefore the resource potential for these commodities is low.

EXPLANATION

[Energy resource potential for oil and gas is moderate, with certainty level B, except that zones of igneous intrusion or extensive hydrothermal alteration have low energy resource potential for oil and gas, with certainty level B. Entire study area has low mineral and energy resource potential for (1) manganese, barite, coal, and geothermal energy, with certainty level B, and (2) vermiculite, with certainty level D]

H1/C — Geologic terrane having high mineral resource potential for commodity 1, with certainty level C

H2/C — Geologic terrane having high mineral resource potential for commodity 2, with certainty level C

M3/B — Geologic terrane having moderate mineral resource potential for commodity 3, with certainty level B

M4/B — Geologic terrane having moderate mineral resource potential for commodity 4, with certainty level B

L/B — Geologic terrane having low mineral resource potential for all metals, with certainty level B

Commodities

1 Vein (including breccia-vein), replacement (including manto), porphyry, stockwork, and (or) tactite-type deposits of lead, silver, copper, zinc, and (or) gold

2 Vein (including breccia-vein), replacement (including manto), porphyry, stockwork, and (or) tactite-type deposits of lead, silver, copper, zinc, arsenic, antimony, and (or) gold, and disseminated gold

3 Vein deposit of antimony

4 Vein, stockwork, porphyry, and (or) tactite-type deposits of tungsten, molybdenum, and (or) tin

Certainty levels

B Data indicate geologic environment and suggest level of resource potential

C Data indicate geologic environment and resource potential but do not establish activity of resource-forming processes

D Data clearly define geologic environment and level of resource potential, and indicate activity of resource-forming processes in all or part of study area

---→ Jeep trail

INTRODUCTION

The BLM (U.S. Bureau of Land Management) requested that 23,690 acres of the Mormon Mountains Wilderness Study Area (NV-050-161) be studied by the USBM and the USGS. This 23,690-acre area, referred to

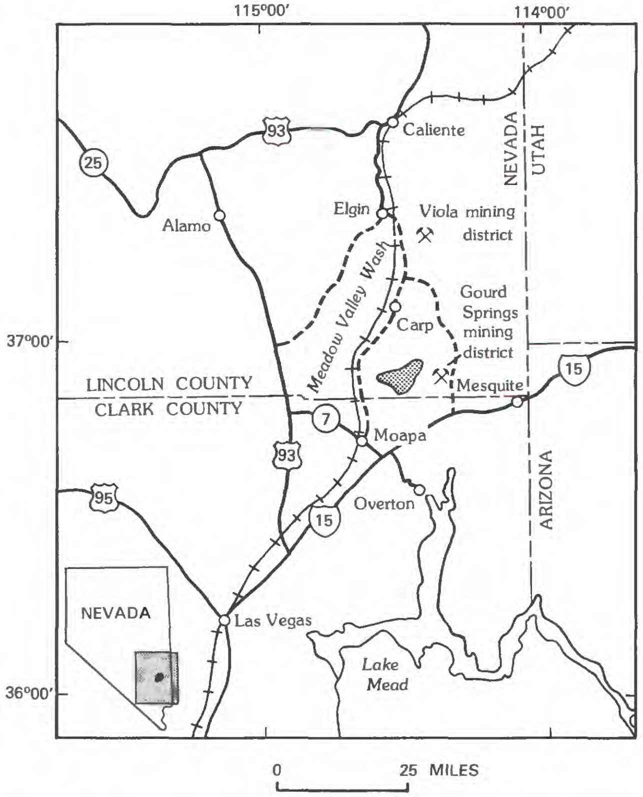


Figure 2. Index map showing location of the Mormon Mountains Wilderness Study Area (stippled), Lincoln County, Nevada.

as the study area in this report, is in Lincoln County, Nev., 60 mi northeast of Las Vegas, and 10 mi southeast of Carp in the core of the Mormon Mountains (fig. 2). Access into the study area is limited to one unimproved jeep trail from Meadow Valley Wash (fig. 1). Several jeep roads lead up to the boundary from Meadow Valley Wash and from the Carp–Mormon Mesa road (fig. 1).

Topographic relief in the study area is about 4,000 ft, ranging from 3,440 ft at the western boundary to 7,414 ft at Mormon Peak (fig. 1 and pl. 1). Lower parts of the study area are sparsely covered with desert shrubs and Joshua trees. The higher elevations have piñon pine and juniper trees along with some ponderosa pine near Mormon Peak. Davies Spring is the only perennial spring in the study area.

This report presents an evaluation of the mineral endowment (identified resources (known) and mineral resource potential (undiscovered)) of the study area and is the product of several separate studies by the USBM and the USGS. Identified resources are classified according to the system of the USBM and USGS (1980), which is shown in the Appendix. Identified resources are studied by the USBM. Mineral resource potential 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 geothermal sources). It is classified according to the system of Goudarzi (1984), which is shown in the Appendix. The potential for undiscovered resources is studied by the USGS.

Investigations by the U.S. Bureau of Mines

Records and publications of the USBM, USGS, and Nevada State agencies were researched for data related to mineral deposits in or near the Mormon Mountains study area prior to field examination. Lincoln County mining claim records and BLM records were examined for claim and lease information.

Personnel from the USBM conducted a field examination of the study area in October-November 1984 and April 1985. During that time, 40 rock samples were collected and fire assayed for gold and silver and analyzed by colorimetric, atomic absorption, radiometric, or X-ray fluorescence methods for other elements to determine presence and abundance of identified or suspected minerals of economic value. At least one sample from each mineralized area was analyzed by semiquantitative methods for 40 elements; amounts of significant elements were then determined by one of the quantitative methods. Three samples were examined petrographically to determine rock types and mineral assemblages. All samples were analyzed by USBM Reno Research Center, Reno, Nev.

Detailed results of the studies by the USBM are given in Rains (1986) and are available from the USBM Western Field Operations Center, E. 360 Third Avenue, Spokane, Wash. 99202.

Acknowledgements.—Arel McMahan and Ed McHugh, USBM geologists, assisted with field examinations for this study.

Investigations by the U.S. Geological Survey

The geology of the Mormon Mountains (Wernicke, 1982) was mapped, in part under contract to the USGS, by B.P. Wernicke (Harvard University), G.J. Axen (Northern Arizona University), and assistants, intermittently from 1979–1985. Detailed mapping was done at 1:12,000 and 1:24,000 scales; the northeasternmost part of the map area was done by reconnaissance and photogeologic methods. The detailed mapping was generalized to a scale of 1:50,000 for the map that accompanies this report (pl. 1).

Geochemical studies of stream sediments and rock samples were made in the field by H.N. Barton and G.W. Day in June 1983 (Barton and Day, 1984). D.R. Shawe collected rock samples in the Mormon Mountains for geochemical study in November 1985. An aeromagnetic survey of the region of the Mormon Mountains was flown at 1-mi spacing by the USGS in 1983. Ground gravity surveys of the region were conducted by H.R. Blank, assisted by J.H. Hassemer, in November 1985; parts of the Mormon Mountains inaccessible on the ground were surveyed by Blank in November 1985 using a helicopter.

Acknowledgements.—J.B. Hansen, then of the USGS, assisted Wernicke and Shawe in the field in November 1985.

APPRAISAL OF IDENTIFIED RESOURCES

By R.L. Rains
U.S. Bureau of Mines

Mining History

Mining in the Viola mining district, 15 mi north of the study area (fig. 2), started in the 1880's and probably spurred exploration of the Mormon Mountains, which led to the discovery of the Whitmore mine and Iron Blossom prospect. Silver and copper were the main ores mined from the Viola district until 1958, when Wells Cargo mined about 11,500 tons of fluorspar (Tschanz and Pampeyan, 1970, p. 165). The Gourd Springs mining district (fig. 2) in the East Mormon Mountains, about 10 mi east of the study area, has produced little ore. In 1929, 60 tons of manganese was mined from the Gourd Springs district. Tungsten prospecting began in the 1940's (Tschanz and Pampeyan, 1970, p. 176), although no tungsten was produced from the Gourd Springs district.

In 1981, Vulcan Energy, Inc. filed 440 placer claims on alluvial fans southeast and southwest of the study area. Currently (1985), about 10 placer claims are located northeast of Horse Spring (fig. 1).

Mines, Prospects, and Mineralized Areas

The Whitmore mine and the Iron Blossom prospect, both just outside the study area, were examined in detail; no resources were identified at those localities. Samples from within the study area were collected to evaluate the quality of the limestone. Detailed sample analyses are given in Rains (1986).

Whitmore Mine

The Whitmore mine was originally called the Bradfute Copper mine. Samuel and Brig Whitmore claimed the Bradfute Copper mine as the Anna Laura, Climax, and Stanley quartz claims in 1899. Three adits totaling

190 ft (the longest 130 ft on a 20° decline), four shafts (the deepest 20 ft), and five prospect pits are on the property. The deposit is in and near a 3- to 4- ft-thick quartz vein that occupies a thrust-fault zone. The upper thrust plate is composed of Cambrian limestone with some interbedded quartzite. The lower plate is Early Proterozoic metamorphic and granitic rock; workings associated with the vein are in granitic rock of the lower plate. Stringers and blebs of chalcopyrite and copper carbonates are exposed in the quartz vein and in associated sheared rock along the easternmost exposure of the vein. The vein itself consists of milky angular quartz fragments as much as 6 in. across, cemented with white to light-red-brown quartz. The vein strikes northeast, dips about 25° NW., and is exposed intermittently for 1,500 ft along strike. Small faults, which offset the vein, are exposed in stream drainages.

Twenty-six samples were taken from surface and underground exposures. Four samples had trace amounts of gold, eight had 0.1–0.6 oz/ton (ounce per ton) silver, and all had minor amounts of copper. One select sample had 3.6 percent copper.

Iron Blossom Prospect

A 12-ft shaft and two open cuts (8 by 30 ft and 50 by 100 ft) were excavated at the Iron Blossom prospect probably around the turn of the century. Howard Knighten claimed the prospect in 1960 and last did assessment work in 1983. The deposit consists of sheared and silicified iron oxides along the contact of Tertiary rhyolites and Paleozoic limestones. Non-silicified iron oxides tend to be concentrated in two zones, whereas pods of silicified iron oxides are scattered along the contact. The iron oxides are deep reddish brown to red and are friable. The silicified iron oxides are brown, jasper-like, have conchoidal fracture, and replace limestone in zones as much as 20 ft wide. Some cracks and vugs are filled with yellow jarosite crystals [$KFe_3(SO_4)2(OH)_6$]. No metallic sulfides were observed.

Eight samples were taken from the iron-oxide zones. Neither gold nor silver was detected; most samples had minor amounts of copper, lead, and zinc.

Limestone

Six random chip samples of limestone were collected and analyzed. Sample sites are shown on plate 1. Samples 1 and 2, probably from the Mississippian Monte Cristo Limestone, meet industry standards for cement manufacturing and for agricultural purposes (Danner, 1966, p. 55). Sample 3 contains too much silica and samples 4, 5, and 6 contain too much magnesia to meet industry standards for cement manufacturing. Neither gold nor silver was detected in the six samples.

Conclusions

No metallic mineral resources were identified within the study area. Only trace amounts of silver and minor amounts of copper were detected at the Whitmore mine. The quartz vein at the mine trends toward the study area, but could not be found there on the surface. The rhyolite-limestone contact at the Iron Blossom prospect extends into the study area, but no gold, silver, copper, lead, or zinc were found along it.

Sample results suggest that some limestone in the study area may meet industrial standards for cement manufacturing or agricultural purposes, but its extent was not determined. Production of limestone is unlikely because it would have to be transported about 60 mi to Las Vegas, the nearest market, and there compete with similar limestone being quarried about 10 mi northeast of Las Vegas. The limestone in the study area is not classified as an identified resource.

No occurrences of oil, gas, or geothermal resources are known, although the entire study area is blanketed with oil and gas leases.

The study area contains small occurrences of sand and gravel, but Meadow Valley Wash to the west of the study area contains enough sand and gravel to supply the needs of the local population for the foreseeable future. Sand and gravel in the study area is not classified as an identified resource because it is not economically recoverable in the foreseeable future.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

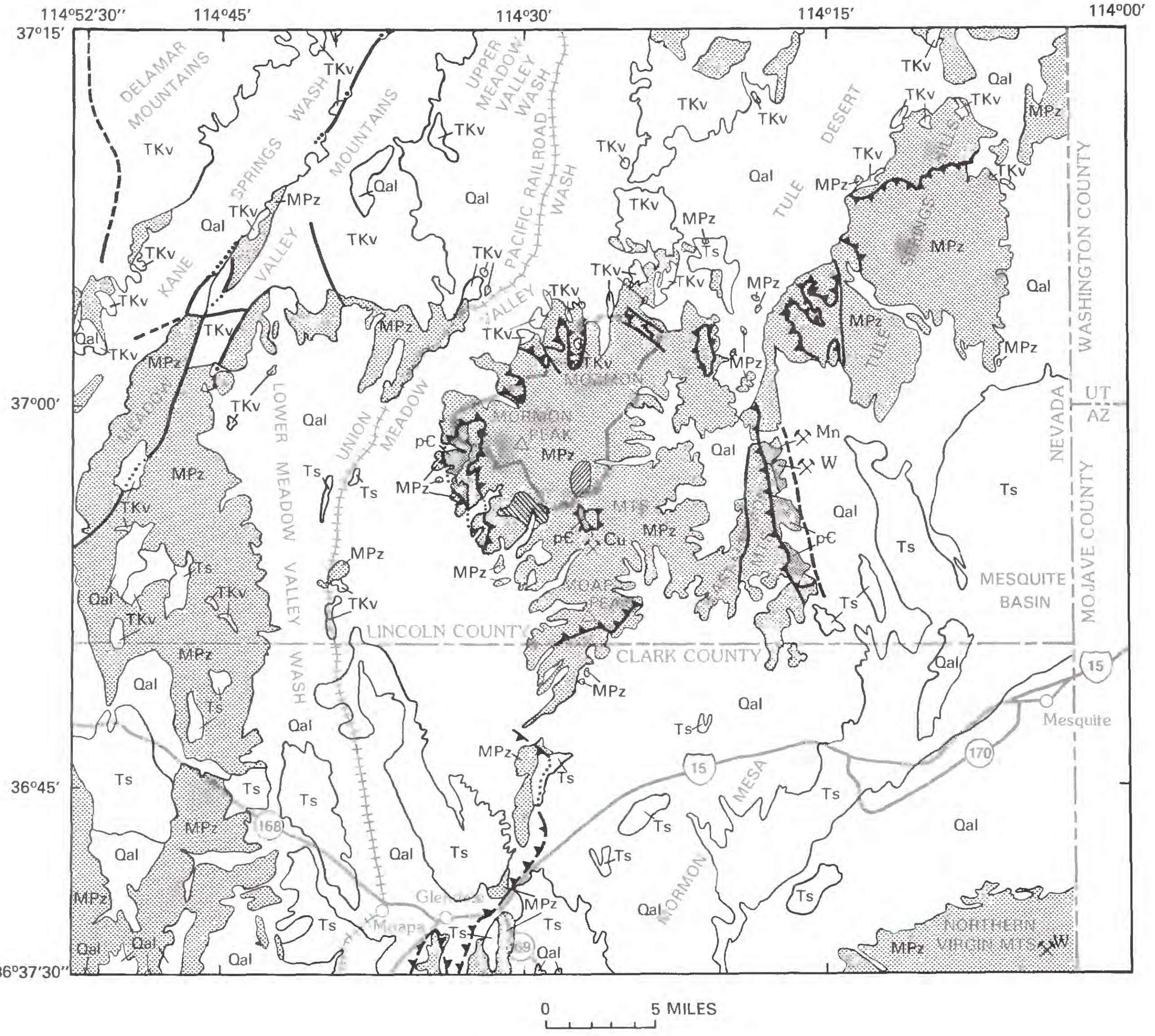
**By D.R. Shawe, H.R. Blank, Jr., B.P. Wernicke, G.J. Axen, H.N. Barton, and G.W. Day
U.S. Geological Survey**

Geology

The generalized geology of the Mormon Mountains Wilderness Study Area and vicinity is shown on figure 3 and plate 1.

Geologic Setting

The Mormon Mountains Wilderness Study Area constitutes only a small area near the south end of the Nevada-Utah section of the large Basin-range tectonic province. Some geologic events that have affected the study area cannot be established from information acquired within the study area, but they can be inferred



EXPLANATION

Qal	Quaternary alluvium
Ts	Tertiary sedimentary rocks
TKv	Tertiary-Cretaceous volcanic rocks
MPz	Mesozoic-Paleozoic sedimentary rocks
p€	Precambrian igneous and metamorphic rocks
	Geologic contact
	High-angle fault—Dashed where inferred; dotted where concealed
	Low-angle fault—Dashed where inferred; dotted where concealed. Sawteeth on upper plate
	Approximate crest of dome on Mormon Peak detachment (allochthon dome)
	Approximate crest of dome on Tapeats Sandstone (autochthon dome)
	Approximate boundary of Mormon Mountains Wilderness Study Area
W	**Mine**—Showing principal commodity extracted: Cu, copper; Mn, manganese; W, tungsten

Figure 3. Generalized geology of the the Mormon Mountains Wilderness Study Area and vicinity, Nevada. (Geology generalized from Tschanz and Pampeyan, 1970, and Longwell and others, 1979; domal structures after Wernicke, 1982).

from regional geologic relations. A brief review of the geologic history of the region therefore is appropriate.

The discernible geologic history of the region began in Late Proterozoic and early Paleozoic time when a thick sequence of clastic marine sediments derived from erosion of the North American continent to the east was deposited within a trough at the western margin of the continent (much of this discussion of geologic setting is based on Stewart, 1980). Sedimentation lapped onto Early Proterozoic metamorphic and igneous rocks along the eastern edge of the trough. Clastic and carbonate sedimentary rocks of Late Proterozoic and Paleozoic age were compressionally deformed in late Paleozoic time, resulting in thrust faulting and folding west of the Mormon Mountains.

During much of the Mesozoic Era the region was blanketed with shallow marine and continental clastic and carbonate rocks derived in part from erosion of the continent to the east and in part from volcanic island arcs farther west that skirted the margin of the continent. Large volumes of plutonic igneous rocks were emplaced in the crust underlying the volcanic arcs during the Mesozoic. Compressional deformation events affected the region throughout the Mesozoic, culminating with the Sevier orogeny in Cretaceous time. In Mesozoic time some significant zones of strike-slip faulting (essentially nearly horizontal faulting along the direction of fault strike) and a number of igneous complexes were formed in the region of the Sevier belt of mountain building. The complexes, cored by plutonic igneous rocks, were reactivated sporadically, by emplacement of younger igneous rocks, as late as the Cenozoic Era.

In early Cenozoic time strike-slip faulting continued, and volcanism spread widely throughout the region. Volcanic activity reached a peak in late Oligocene-early Miocene time. The Mormon Mountains Wilderness Study Area lies at the south margins of overlapping fields of igneous rocks, one a large, province-wide field that ranges in age from 34–17 million years old, and a smaller field from 17 to as young as 6 million years old.

The youngest phase of compressional deformation was terminated in middle Miocene time, and extensional deformation commenced at that time in the Basin-range tectonic province. This phase of tectonism, still continuing, has been characterized by regional uplift accompanying more crustal thinning, more strike-slip faulting, low-angle normal faulting, and high-angle gravity faulting that has delineated the present generally north-trending mountain ranges of the province.

Description of Rock Units

The following rock units were mapped in the study area (pl. 1, map and cross section; see Wernicke, 1982): Early Proterozoic metamorphic and igneous rocks (unit Xm); Cambrian clastic rocks (unit Єc); Cambrian dolostone (unit Єd); Ordovician to Mississippian dolostone and limestone (unit MOd); Bird Spring Formation (unit PIPb); Tertiary volcanic rocks (unit Tv); and Quaternary alluvium and talus deposits (unit Qa).

Early Proterozoic metamorphic and igneous rocks consist of paragneiss, orthogneiss, schist, migmatite, pegmatite, and granite. Cambrian clastic rocks overlie the metamorphic rocks on a surface of low relief. The clastic rocks consist of the Tapeats Sandstone (correlative with the upper part of the Prospect Mountain Quartzite) and the overlying Bright Angel Shale (correlative with the Pioche Shale). Cambrian dolostone consisting of the Bonanza King and Nopah Formations overlies the clastic rocks. A thin Dunderberg Shale lies between the Bonanza King and the Nopah. Ordovician to Mississippian strata that overlie the Cambrian dolostone consist of the Ordovician Pogonip Group (mostly carbonate), thin Eureka Quartzite, and Ely Springs Dolostone, Devonian Sultan Limestone, and Mississippian Monte Cristo Limestone. No Silurian and Lower Devonian rocks are present in the study area. The Pennsylvanian and Permian Bird Spring Formation of mostly cherty limestone overlies the Monte Cristo Limestone. Tertiary volcanic rocks that unconformably overlie older rocks are lava flows and breccias of rhyolitic, dacitic, and basaltic composition with minor volcaniclastic interbeds, and silicic ash-flow tuffs. A small intrusive latite plug lies 0.5 mi northwest of the Iron Blossom prospect. Quaternary alluvium and talus deposits unconformably overlie older deposits.

Structure

Rocks in the Mormon Mountains Wilderness Study Area and in surrounding parts of the Mormon Mountains are extensively faulted. Low-angle faults divide the rocks generally into four major structural units (Wernicke, 1982; structural cross section, pl. 1). At the lowest level are Proterozoic metamorphic and igneous rocks and Cambrian clastic sedimentary rocks that are rooted to their basement (to which the term "autochthon" is applied). Low-angle faults, locally at the base of the Cambrian section and higher in the section, have displaced overlying rocks (to which the term "parautochthon" is applied) eastward an unknown distance. At a higher structural level, the Mormon thrust fault is a regional fault that has moved overlying rocks (referred to here as the "Mormon thrust plate") perhaps 7–15 mi eastward or northeastward. The generally east-directed overthrusting took place during the Cretaceous Sevier mountain building event. A yet higher low-angle fault, the Mormon Peak detachment, moved overlying rocks (referred to here as the "Mormon Peak allochthon") westward perhaps 20 mi during Miocene extensional deformation. The Mormon Peak detachment dips outward an average of about 1,000 ft/mi around much of the periphery of the Mormon Mountains (Wernicke, 1982), indicating that the surface of the detachment has been significantly domed since emplacement of the allochthon in Miocene time. The center of the dome (labelled allochthon dome on fig. 3, and cross section, pl. 1) lies near the south edge of the wilderness study area and the Whitmore mine. Beneath the detachment fault the Tapeats Sandstone, which overlies Proterozoic basement, is domed (labelled autochthon dome on fig. 3, and cross section, pl. 1) more than the detachment (Wernicke, 1982), showing that doming was initiated before the Mormon Peak allochthon was emplaced. Numerous high-angle faults are present throughout the map area (many are not shown on pl. 1). Some are older than the Mormon Peak detachment and some are younger than the Mormon Peak detachment.

Geophysics

Regional gravity and aeromagnetic data were obtained to assist in assessing the mineral resource potential of the study area. Gravity data are available from files of the DMA (U.S. Defense Mapping Agency) through the National Geophysical and Solar-Terrestrial Data Center (Boulder, CO 80303) and from two published complete Bouguer anomaly maps (Kane and others, 1979; Healey and others, 1981). About 120 additional gravity stations were established during the course of the present investigation with the assistance of J.H. Hassemer of the USGS. Aeromagnetic data are available from two residual total-intensity anomaly maps (Saltus and Snyder, 1986; USGS, 1983). The surveys from which these maps were compiled were flown north-south at 1-mi spacing and 9,000-ft barometric altitude north of lat 37° N., and east-west at 1-mi spacing and 1,000 ft above terrain south of lat 37° N.

Aeroradiometric data were collected from east-west traverses (at 3-mi spacing) flown in conjunction with the NURE (National Uranium Resource Evaluation) program. No anomalies were detected within the boundaries of the Mormon Mountains Wilderness Study Area or in the immediate vicinity (J.S. Duval, written commun., 1985).

Gravity Data

A complete Bouguer gravity anomaly map of the Mormon Mountains Wilderness Study Area and vicinity is shown on figure 4.

The Mormon Mountains are located near the northern extremity of a very broad, generally north- to northeast-trending regional Bouguer anomaly high of some 30–40 mGals (milliGals) amplitude, which occupies the majority of the map area. This high is sharply bounded on the southeast by deep anomaly depressions produced by thick low-density fill beneath Mormon Mesa and the Mesquite Basin, and on the north by a series of east-trending step-like gradients leading toward the Caliente cauldron complex that lies about 25 mi north of the Mormon Mountains. Three crests of the regional high are seen on figure 4. The first and highest maximum (labeled H1 on fig. 4) is located several miles south of the topographic center of the Mormon Mountains and the crest of the broad dome on the Mormon Peak detachment allochthon. The dome on the Mormon Peak detachment is labelled allochthon dome on figure 3, and cross section, plate 1. Two lesser maxima (labeled H2 and H3 on fig. 4) are positioned to the southwest.

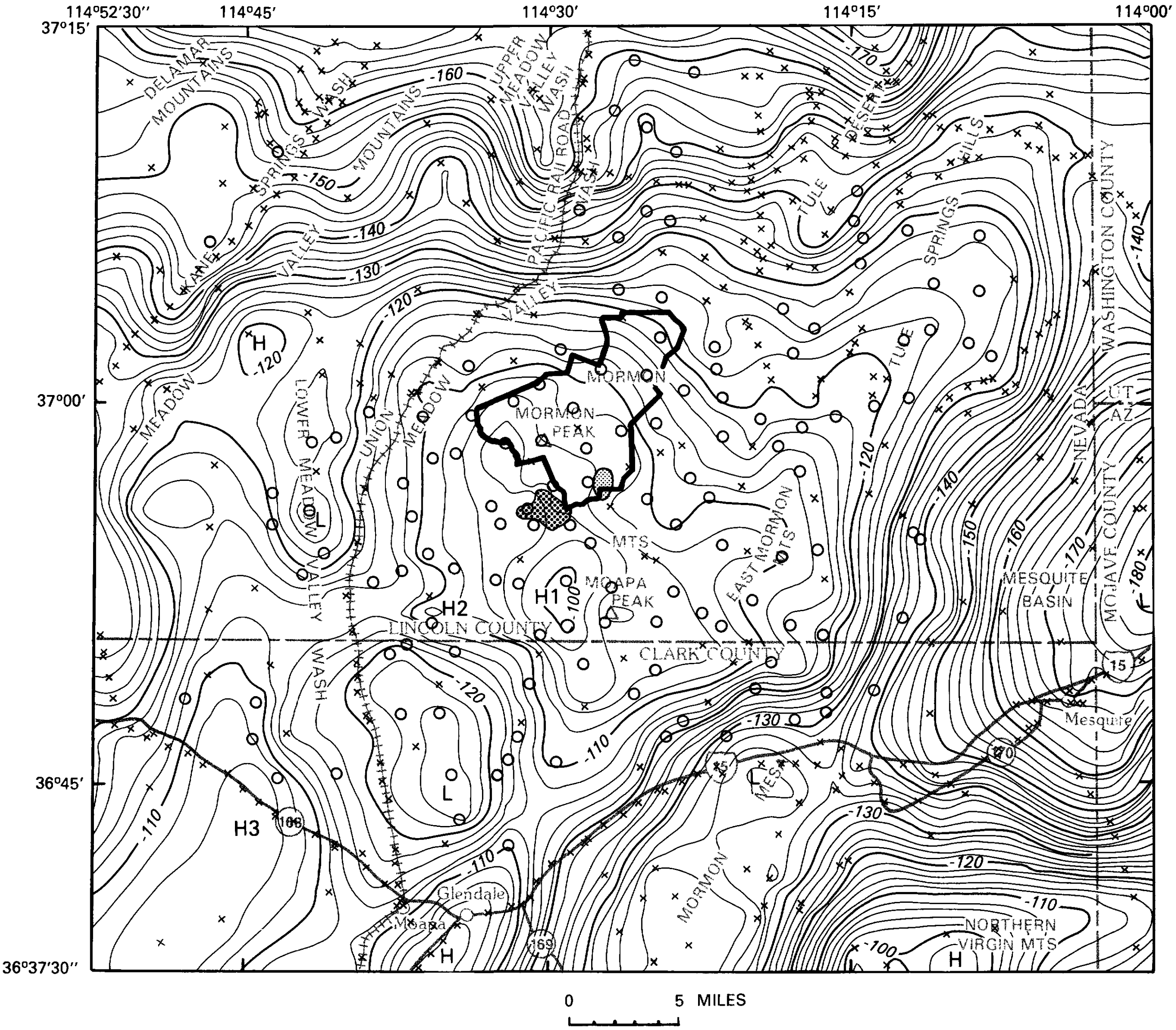
The regional anomaly high with its undulating surface features is interpreted as the expression of a broad swell, or arch, of the Proterozoic crystalline basement and pre-Tertiary cover rocks, which consist mainly of dense carbonate rocks of the Paleozoic succession. In addition it is possible that the basement arch has been locally deformed by high-level crustal magmatism. We believe that the domoform uplift of the Mormon Mountains is at least in part related to emplacement of a granitic intrusive body of late Mesozoic or Tertiary age beneath the western part of the range.

The dome on the Tapeats Sandstone (autochthon dome on figs. 3 and 4 and cross section, pl. 1; Wernicke, 1982) lies slightly north of the gravity maximum. The Tapeats dome and associated basement uplift are more or less central to the collective systems of mineralization mapped in the course of the present investigation. However, the gravity field is inconclusive with respect to the presence or absence of a postulated intrusion beneath the autochthon dome.

Aeromagnetic Data

Figure 5 shows the residual total-intensity magnetic anomaly field (drape elevation of 1,000 ft above terrain) for the same area as that in figure 4. Because of the inclination and declination of the Earth's main magnetic field, anomaly maxima generally do not directly overlie the source bodies but are displaced slightly to the southwest of them, and are accompanied by weaker minima on the northeast sides. There are no known anomaly sources in the Paleozoic sedimentary rock section of southern Nevada; therefore, the map (fig. 5) records only contributions from the Proterozoic crystalline basement and from intrusive and volcanic rocks of Mesozoic or younger age.

The basement arch inferred from regional gravity data is expressed on the aeromagnetic map by two broad anomaly highs, the more northerly of which (labelled H1 on fig. 5) is associated with the Mormon Mountains. Only



EXPLANATION

—-120— **Gravity contour**—Contour interval 2 milliGals. Reduction density 2.67 g/cm³. Terrain corrected from digital topography to 100 mi

H **Gravity high**

L **Gravity low**

Gravity station

× **U.S. Defense Mapping Agency files**

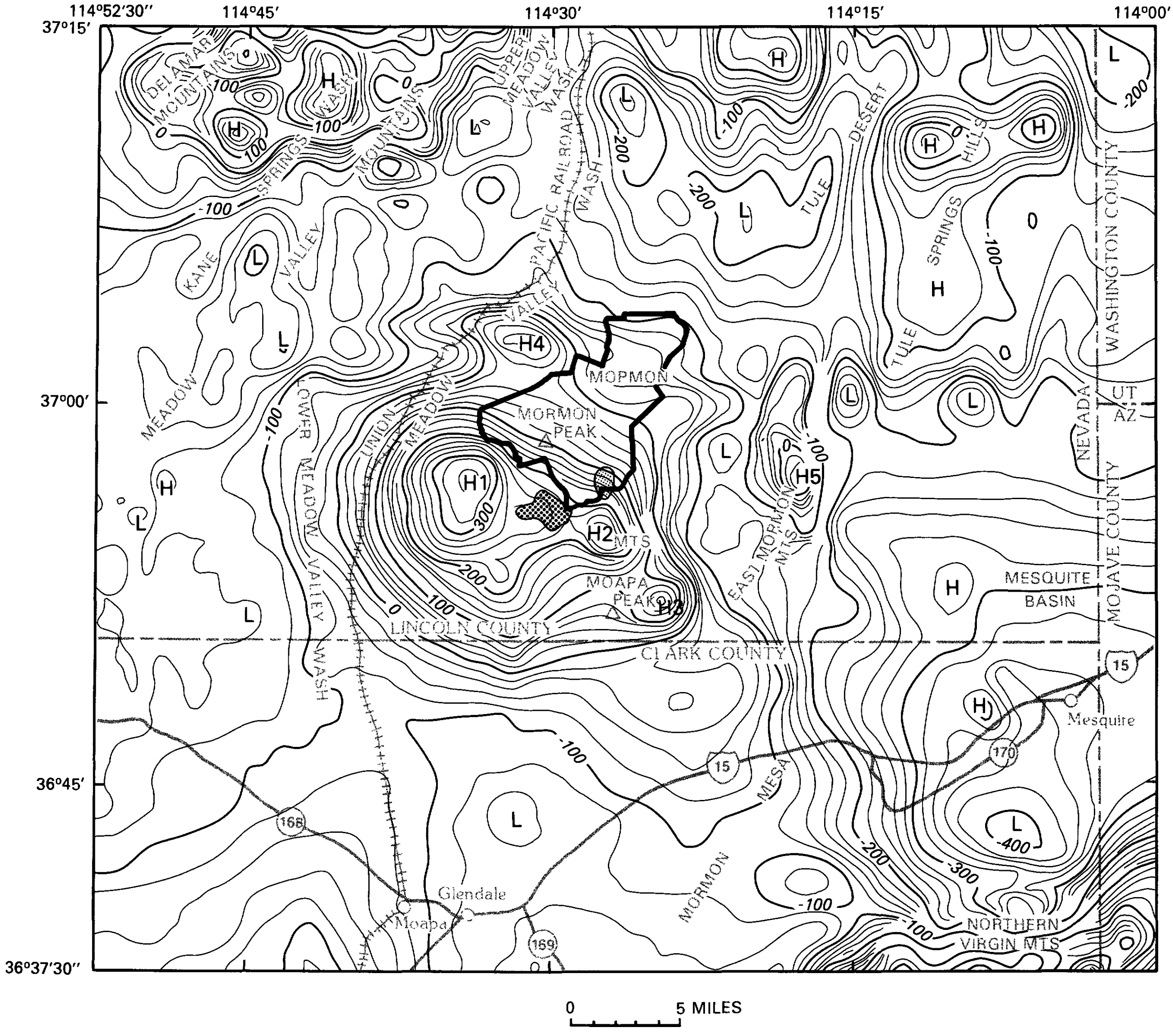
o **This study**

Approximate crest of dome on Mormon Peak detachment (allochthon dome)

Approximate crest of dome on Tapeats Sandstone (autochthon dome)

Approximate boundary of Mormon Mountains Wilderness Study Area

Figure 4. Complete Bouguer gravity anomaly contours of the Mormon Mountains Wilderness Study Area and vicinity, Nevada.



EXPLANATION

—200— **Aeromagnetic contour**—Contour interval 20 nanoTeslas. IGRF removed. Draped 1,000 ft above terrain. For data sources see text

H **Aeromagnetic high**

L **Aeromagnetic low**

Approximate crest of dome on Mormon Peak detachment (allochthon dome)

Approximate crest of dome on Tapeats Sandstone (autochthon dome)

Approximate boundary of Mormon Mountains Wilderness Study Area

Figure 5. Residual total-intensity aeromagnetic anomaly contours of the Mormon Mountains Wilderness Study Area and vicinity, Nevada.

a weak, north-trending nose of the more southerly anomaly is seen on figure 5; this anomaly is centered well to the south of the map area. Clusters of intense, relatively short-wavelength anomalies to the north and northwest of the Mormon Mountains are produced by Tertiary volcanic rocks, and a zone of extremely strong anomalies in the southeast corner of the area of figure 5 is attributable to Teriary volcanics and additional sources associated with the Precambrian core of the northern Virgin Mountains.

Three local maxima (labelled H1, H2, and H3 on fig. 5) delineate the Mormon Mountains aeromagnetic anomaly crest. The highest (H1) in amplitude is located approximately over exposures of Proterozoic crystalline rock on the western margin of the range and just west of the Tapeats (autochthon) dome. A weaker maximum (H2) is associated with crystalline rock exposed in the basement window at the Whitmore mine, due south of the apex of the Mormon Peak detachment (allochthon) dome. The third and weakest maximum (H3) is located at the southeast margin of the range and suggests the presence of basement rocks beneath a thin cover of alluvium.

A prominent east-trending local high (H4) occurs near lat 37° N., long 114°30′ W., on the north flank of the principal anomaly of the range. It probably represents either a discrete area of uplifted basement or a locus of volcanic vents; the latite plug lies on its east nose and other vents could be located farther west where bedrock is concealed.

Another local magnetic high (H5) occurs on the east side of the Mormon Mountains about 7 mi east of the study area as a feature completely isolated from the anomaly of the range. This high is centered over exposures of Proterozoic crystalline basement rock in the East Mormon Mountains.

In order to better delineate the basement geometry, we present a map of the anomalous field continued upward to a constant elevation of 12,500 ft and reduced-to-the-pole (fig. 6). These operations smooth out the contribution of near-surface sources and tend to shift the positions of anomaly maxima more nearly over the centers of the causative bodies, as though the field were recorded at the geomagnetic north pole. The result is an isolated "bullseye" circular magnetic high (labelled H1 on fig. 6) centered directly north of the Tapeats dome in the western part of the Mormon Mountains. This high is coincident with the subcircular part of the gravity anomaly and is offset to the west of the dome of the Mormon Peak detachment.

The source of the bullseye anomaly must reside in the basement, but it is unlikely to be basement relief alone because of the unrealistically high magnetization required. Rough depth-to-source estimates from figure 6 suggest a source depth of about one mile beneath the Proterozoic surface. The fact that a magnetic source body directly underlies the mapped basement dome and systems of mineralization in the overlying Paleozoic and younger strata in our view argues strongly for the existence of a post-Tapeats (probably Miocene) intrusion genetically related both to the uplift and to the mineralization.

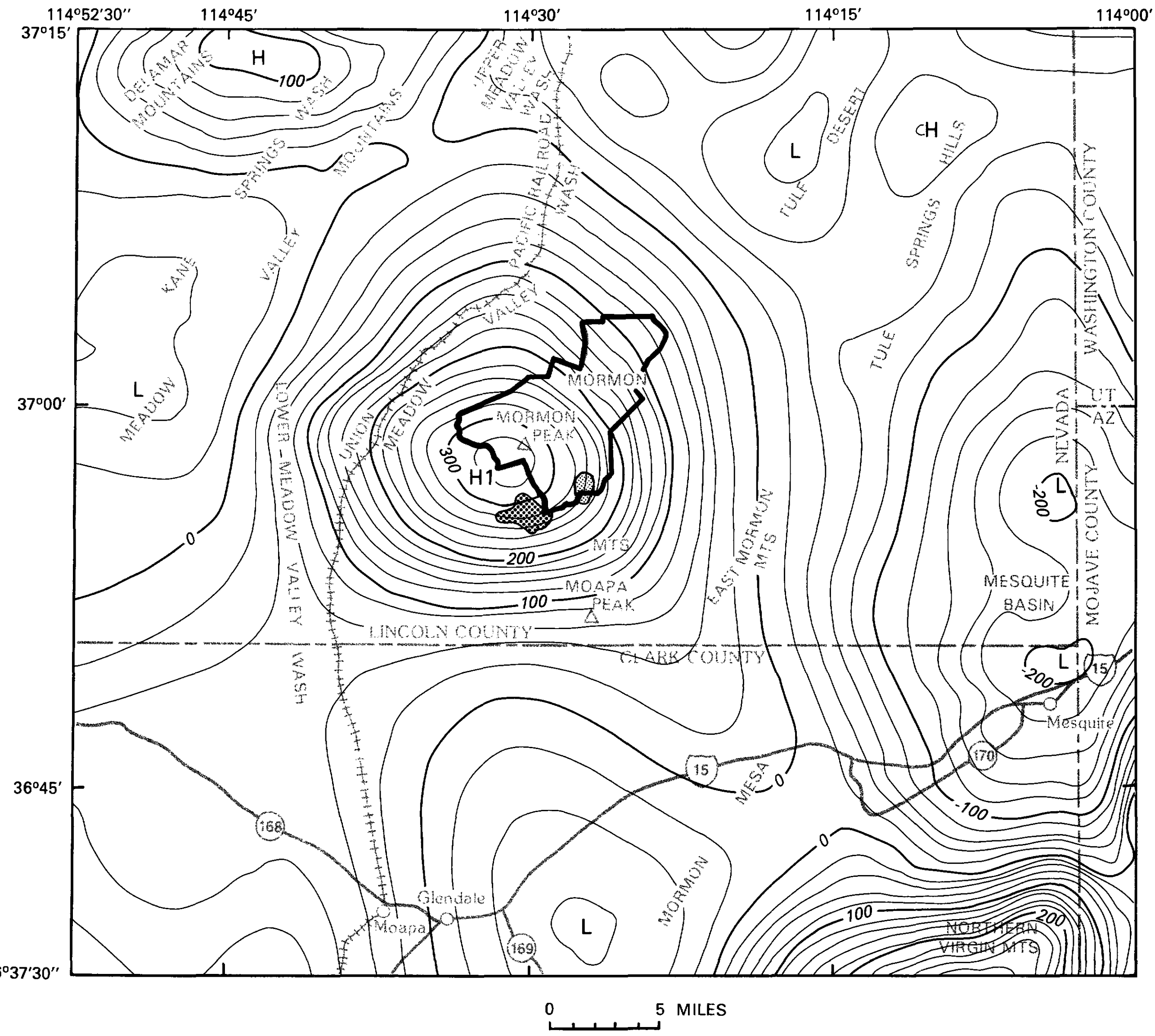
Geochemical Investigations and Mineralized Rocks

Analytical Methods

Stream-sediment samples were collected from first- and second-order drainages in and near the Mormon Mountains Wilderness Study Area (pl. 1). Sampling was conducted in June 1983 as part of a larger reconnaissance geochemical survey of the entire Mormon Mountains (Barton and Day, 1984), not just the 23,690-acre study area. For each of 191 sample localities, a heavy-mineral concentrate and a minus-10-mesh composited sample were analyzed. Samples taken for preparation of heavy-mineral concentrates were selected to give a high yield of heavy minerals that may be associated with ore deposits. Following panning and screening to minus 30-mesh, heavy-mineral concentrates were processed through bromoform and an isodynamic separator to obtain nonmagnetic heavy-mineral fractions for analysis.

All samples were analyzed semiquantitatively for 31 elements by a six-step, direct-current arc, optical-emission, spectrographic method (Grimes and Marranzino, 1968). Of the 31 elements analyzed, anomalous concentrations of antimony, arsenic, barium, bismuth, boron, copper, iron, lead, manganese, molybdenum, silver, tin, tungsten, and zinc may indicate areas of mineral resource potential. Analytical data for all of the stream-sediment and heavy-mineral-concentrate samples collected were given by Barton and Day (1984).

Twenty-five rock samples were collected in the 1983 geochemical reconnaissance by Barton and Day (1984), and an additional 90 were collected in and near the study area in November 1985 by Shawe and J.B. Hansen. All of the samples were analyzed semiquantitatively for 31 elements by the spectrographic method, and in addition the 90 samples collected by Shawe and Hansen were analyzed for uranium, thorium, thallium, tungsten, mercury, gold, arsenic, and antimony by various radiochemical, chemical, spectrographic, and activation methods of analysis. The analyses show that most of the rock samples contain anomalous amounts of iron, manganese, silver, arsenic, barium, copper, molybdenum, lead, antimony, tin, tungsten, zinc, mercury, gold, thorium, uranium, or thallium. Analytical data for rock samples that have anomalous concentrations of elements are given in table 1.



EXPLANATION

—300— Aeromagnetic contour—Contour interval 20 nanoTeslas. IGRF removed. Upward continued to 12,500 ft above sea level. For data sources see text

H Aeromagnetic high

L Aeromagnetic low

Approximate crest of dome on Mormon Peak detachment (allochthon dome)

Approximate crest of dome on Tapeats Sandstone (autochthon dome)

Approximate boundary of Mormon Mountains Wilderness Study Area

Figure 6. Residual upward-continued aeromagnetic anomaly contours of the Morman Mountains Wilderness Study Area and vicinity, Nevada.

Results of Studies

Stream-sediment and rock samples collected in and near the study area show that the Mormon Mountains are widely mineralized. The stream-sediment samples and heavy-mineral concentrates from stream sediments indicate broad areas of lead, arsenic, antimony, silver, copper, zinc, molybdenum, tungsten, and tin mineralization, summarized on plate 1 and figure 1. More than 80 samples in and near the study area show anomalous concentrations of one or more of these metals.

Stream-Sediment Samples

Lead is anomalous in a broad zone that includes much of the south half of the study area. Values range from 200 to 30,000 ppm (parts per million) lead in heavy-mineral concentrates. Anomalous concentrations of copper in heavy-mineral concentrates from the southern zone are locally as high as 100 ppm. In a smaller zone in and near the north part of the study area values are 200-5,000 ppm lead in heavy-mineral concentrates. Locally in these lead-enriched zones anomalous silver values range from 5 to 20 ppm. In the northern mineralized zone anomalous copper values in heavy-mineral concentrates are 200 ppm and in stream-sediment samples 100–150 ppm. A zone of enrichment in arsenic (500–1,500 ppm) coincides with the zone of lead, silver, and copper enrichment in the north part of the study area. Also coincident with the northern zone and extending southwestward from the zone toward the southern zone of lead and silver enrichment is an area in which antimony values in heavy-mineral concentrates range from 200 to 2,000 ppm. A zone of mineralization characterized by tungsten enrichment (<100–200 ppm in heavy-mineral concentrates) lies at the west-central boundary of the study area, and a zone of molybdenum enrichment (50–100 ppm in heavy-mineral concentrates) lies in the east-central part of the study area. Surrounding this central core of tungsten-molybdenum enrichment and throughout the Mormon Mountains are local zones of tin enrichment (50–500 ppm in heavy-mineral concentrates and 70 ppm in a stream-sediment sample). Zones of zinc enrichment in and near the study area are not related particularly to concentrations of any other metal. They are most abundant on the east side of the Mormon Mountains where anomalous values range from 500 to 5,000 ppm in heavy-mineral concentrates.

Rock Samples

Analytical data for mineralized rock samples collected around the periphery of the study area (table 1; pl. 1) corroborate the evidence for mineralization indicated by the stream-sediment samples and heavy-mineral concentrates. They also provide evidence for the sources of anomalous metals in the sediment samples. Anomalous lead values were detected in samples 260 (1,500 ppm) and 283 (150 ppm), which were collected from iron-oxide-rich zones (gossans) in dolomite in the southern zone of anomalous lead in stream sediments. Sample 260 represents material from a north-northeast-trending high-angle fault that offsets the Mormon Peak detachment fault. Anomalous silver (1.5–10 ppm) and (or) copper (200–>20,000 ppm) were detected in mineralized samples (281, 282A, 282B, 283, 306B) collected at and near the Whitmore mine, principally from low-angle faults at the base of Cambrian dolostone. Anomalous copper also was found in (1) iron-mineralized silicified veinlets in tuff (sample 286, 100 ppm) that form a stockwork at the Iron Blossom prospect (the stockwork is centered in the northern zone of anomalous metals) and (2) an iron-mineralized quartz pod in Proterozoic amphibolite (sample 270, 100 ppm) near the west margin of the study area. Anomalous arsenic (200–6,300 ppm) was detected in more than half the samples (table 1) collected around the study area; it is most consistent and high in samples collected at and near the Iron Blossom prospect in the northern zone of anomalous metals. Most of the arsenic-enriched samples collected at the Iron Blossom prospect are from brecciated rocks in or slightly above the Mormon Peak detachment. Sample H31, iron-mineralized breccia of the Pennsylvanian and Permian Bird Spring Formation collected along a young range-front fault near the west end of the northern zone, contains 450 ppm arsenic. Sample 278, iron-mineralized Ordovician Pogonip carbonate rock collected along a north-trending fault west of the Whitmore mine, contains 740 ppm arsenic. Antimony is anomalous in sample 274 (28 ppm), which was collected from a mineralized, sheared, and brecciated north-trending fault in Cambrian dolostone west of the Whitmore mine, and in samples 284 (37 ppm) and 285 (27 ppm), which were collected in iron-mineralized dolostone in a low-angle fault at the base of Cambrian dolostone south of the Whitmore mine. Antimony shows highest values at the margin of the hornblende latite plug (samples 294, 83 ppm; 296, 85 ppm) and in jasperized cherty dolostone and limestone of the Pennsylvanian and Permian Bird Spring Formation (samples 298, 39 ppm; 299, 230 ppm), all collected about 0.5 mi west and northwest of the Iron Blossom prospect.

Anomalous concentrations of other elements, mostly metals, were detected in mineralized samples collected around the periphery of the Mormon Mountains Wilderness Study Area. Concentrations of iron (5–>20 percent) and zinc (120–4,200 ppm) are found in many samples, and concentrations of manganese (2,000–5,000 ppm) and barium (1,000–1,500 ppm) are sporadic. Sample H30, consisting of iron-mineralized breccia collected along a young range-front normal fault near the west end of the northern zone of anomalous metals, contains 1,000 ppm barium. Sample 243, which contains anomalous zinc (240 ppm), is from a brown algal chert layer in Cambrian dolostone in the upper plate of the Mormon thrust fault and underlying

Table 1. Analytical data for mineralized rock samples collected near the Mormon Mountains Wilderness Study Area.

[Values in ppm, except Fe in percent; lower limits of determination in parentheses. Fe, Mn, Ag, As, Ba, Cu, Mo, Pb, Sb, Sn, and Zn analyzed by six-step spectrographic method by M.J. Malcolm and D.L. Fey; W analyzed by ion exchange and induction plasma method by B.J. Libby; Tl analyzed by chemical extraction and atomic absorption method by M.W. Doughten; Hg analyzed by nitric acid-potassium dichromite digestion and cold-vapor atomic absorption method by C.A. Gent; Au analyzed by hydrogen bromide-bromine digestion and atomic absorption method by T.M. McCollom; Th and U analyzed by radiochemistry method by R.B. Vaughn and D.M. McKown. ND, not determined; <, less than; > greater than]

Sample No.	Area	Fe	Mn (10)	Ag (0.5)	As (5)	Ba (20)	Cu (5)	Mo (5)	Pb (10)	Sb (2)	Sn (10)	W (1)	Zn (2)	Hg (0.02)	Au (0.1)	Th	U	Tl (0.02)
M347	Whitmore mine	20.00	50	<0.5	300	<20	ND	50	30	<100	<10	<50	1,000	ND	<20	<200	ND	ND
274		0.2	30	<0.5	110	20	<5	<5	<10	28	<10	1.8	<2	0.04	<0.1	<1.8	0.6	2.9
276		1.0	100	<0.5	31	100	5	<5	50	9	<10	<1	22	0.03	<0.1	5.2	2.4	2.0
277		10.0	30	<0.5	360	30	<5	<5	20	<2	<10	<1	21	<0.02	<0.1	<2.2	1.6	1.1
278		1.0	150	<0.5	740	<20	<5	<5	<10	<2	<10	1.2	<2	<0.02	<0.1	<2.2	1.3	16
279		0.2	70	<0.5	26	<20	<5	7	<10	<2	<10	<1	9	<0.02	<0.1	<2.1	1.6	0.5
281		3.0	<10	10	150	1,000	>20,000	<5	<10	7	<10	3.6	210	0.61	0.2	<6.4	20.5	0.2
282A[1]		7.0	100	10	250	1,000	>20,000	<10	15	18	<10	1.4	50	ND	<0.1	<2.7	5.3	0.6
282B		2.0	70	1.5	250	50	20,000	<5	<10	6	<10	1.5	14	0.15	<0.1	<1.5	1.2	0.1
283		7.0	30	<0.5	300	<20	200	7	150	4	<10	2.1	240	0.16	<0.1	<1.7	2.0	2.3
284		5.0	70	<0.5	6,300	<20	70	<5	15	37	<10	7.8	68	1.75	<0.1	<1.9	2.3	31
285		1.0	30	<0.5	1,500	<20	20	<5	70	27	<10	<1	280	1.42	<0.1	<1.6	1.6	1.1
306A		3.0	3,000	<0.5	20	700	<5	<5	<10	6	<10	<1	41	0.04	<0.1	<2.8	2.6	0.9
306B		7.0	2,000	<0.5	1,900	1,000	200	5	<10	3	<10	9.1	33	0.18	<0.1	5.0	3.5	9.8
306C		15.0	30	<0.5	110	70	5	<5	<10	<2	<10	58	5	0.03	<0.1	5.7	4.2	0.5
254	Southwest	1.0	50	<0.5	42	100	7	<5	20	11	<10	1.8	14	0.04	<0.2	<4.4	10.7	1.0
256		0.7	50	<0.5	100	<20	<5	<5	50	16	<10	3.2	880	<0.02	<0.1	<2.1	2.6	1.3
258		2.0	50	<0.5	220	70	30	<5	50	18	<10	3.7	9	3.0	<0.1	<3.1	5.5	2.1
260		>20.0	30	<0.5	330	50	15	10	1,500	15	<10	18	700	ND	<0.1	<7.0	26.8	2.0
263A		7.0	300	<0.5	35	300	7	7	<10	<2	<10	4.5	17	0.04	<0.1	8.9	4.9	1.5
263B		5.0	150	<0.5	34	70	10	<5	<10	6	<10	12	9	<0.02	<0.1	<3.4	5.3	1.0
263D		7.0	5,000	<0.5	240	700	10	<5	20	8	<10	18	18	ND	<0.1	18.8	14.1	5.6
269	West	0.7	70	<0.5	<5	15	<5	<5	10	<2	20	3.7	<2	0.02	<0.1	8.2	3.9	0.7
270		7.0	70	<0.5	47	70	100	10	<10	<2	<10	<1	40	ND	<0.1	<2.0	1.4	0.1
272		0.7	70	<0.5	<5	300	<5	<5	15	<2	30	1.7	<2	<0.02	<0.1	3.5	1.9	2.8
H30	Northwest	3.0	15	<0.5	170	1,000	<5	<5	15	7	<10	7.4	25	0.07	<0.1	19.5	5.1	1.7
H31		1.0	150	<0.5	450	200	7	<5	<10	17	<10	4.6	23	0.05	<0.1	<2.5	2.7	1.1
286	Iron Blossom prospect.	5.0	300	<0.5	530	150	100	<5	15	7	<10	7.5	870	0.04	<0.1	18.7	7.3	3.2
287A		15.0	<10	<0.5	370	70	20	<5	15	<2	<10	7.7	43	ND	<0.1	<8.3	25.5	0.2
287B		>20.0	<10	<0.5	4,600	200	10	<5	15	<2	<10	2.2	88	ND	<0.1	4.7	1.7	0.2
287C		>20.0	<10	<0.5	2,800	150	7	<5	10	<2	<10	<1	26	ND	<0.1	6.4	2.6	0.3
288		15.0	50	<0.5	3,200	150	7	<5	<10	<2	<10	14	250	ND	<0.1	10.9	6.2	0.8
289		7.0	200	<0.5	1,300	1,000	50	<5	15	15	<10	20	780	0.69	<0.1	15.7	4.4	4.3

290		20.0	300	<0.5	4,300	150	10	10	<10	10	<10	13	4,200	1.09	<0.1	15.6	11.5	11
294		3.0	50	<0.5	4,300	700	15	<5	15	83	<10	31	81	1.29	<0.1	10.0	1.8	11
296		7.0	150	<0.5	3,000	1,500	15	20	10	85	<10	12	79	2.23	<0.1	<2.9	5.3	4.1
298		0.7	300	<0.5	360	150	10	7	10	39	<10	2.1	120	0.50	ND	<2.8	5.4	1.7
299		15.0	150	<0.5	2,600	150	20	15	15	230	<10	7.7	200	0.44	<0.2	<2.8	5.8	3.9
301		2.0	70	<0.5	480	150	7	30	<10	15	<10	<1	5	0.32	<0.1	<1.6	1.1	0.3
243	Northeast	0.3	50	<0.5	9	70	<5	<5	20	8	<10	<1	240	<0.02	<0.1	4.7	2.3	0.2
302		3.0	30	<0.5	370	150	5	<5	20	15	<10	13	54	0.09	<0.1	24.1	7.4	1.9
304		2.0	100	<0.5	140	100	<5	<5	15	8	<10	9.5	22	0.09	<0.1	21.4	5.7	1.4
305		1.5	300	<0.5	360	200	<5	<5	15	12	<10	8.0	85	0.32	<0.1	21.1	7.6	3.8

[1] Sample contains 15 ppm Bi (six-step spectrographic method; lower limit of determination 10 ppm).

SAMPLE DESCRIPTIONS

M347 Brown algal-chert layer at top of light-gray dolomite unit.
254 Iron-mineralized silty dolomite along northerly steep fault.
256 Limonitic breccia at base of detachment fault.
258 Iron-stained silty dolomite.
260 Gossanlike material along north-northeasterly high-angle fault.

263A Limonite-rich Proterozoic phyllitic schist, at prospect pit.
263B Red iron-oxide-rich Proterozoic phyllitic schist, at prospect pit.
263D Ocherous "gouge" along flat fault, at prospect pit.
269 Micaceous Proterozoic pegmatite.
270 Iron-mineralized quartz pod in Proterozoic amphibolite.

272 Hematitic, pegmatitic Proterozoic granite.
274 Sheared, brecciated, iron-mineralized dolomite along northerly steep fault.
276 Iron-mineralized brecciated Ordovician Pogonip dolomite on northerly fault.

277 Gossan and jasperoid along N. 80° W. fault.
278 Iron-mineralized Ordovician Pogonip dolomite along northerly fault.
279 Iron-mineralized breccia along northwesterly fault.
281 Copper-mineralized material along low-angle fault.
282A Chalcopyrite-rich mineralized Proterozoic granite, at prospect pit.

282B Silicified vein material, at prospect pit.
283 Gossan in dolomite.
284 Iron-mineralized brecciated dolomite.

285 Sheared, brecciated, iron-mineralized dolomite.
286 Limonitic tuff of stockwork.
287A Hematitic tuff, Iron Blossom prospect pit.
287B Jarosite-rich mineralized tuff, Iron Blossom prospect pit.
287C Jarosite-rich mineralized tuff, Iron Blossom prospect pit.

288 Gossan in brecciated hematitic tuff.
289 Argillically altered tuff.
290 Limonitic gossan at base of tuff.
294 Iron-mineralized dolomite and tuff(?) near latite plug.
296 Iron-mineralized rock at latite plug margin.

298 Jasperized cherty dolomite.
299 Gossany jasperoid in Mississippian Monte Cristo Limestone.
301 Iron-mineralized sedimentary layer in volcanic tuff.
302 Silicic tuff with reddish-brown and yellowish-brown iron oxides.

304 Reddish-brown iron-stained tuff.
305 Limonitic tuff.
306A Iron-rich breccia along low-angle fault separating Cambrian Tapeats Sandstone and overlying limestone.
306B Limonitic gouge-breccia.

306C Hematitic fault material.
H30 Iron-mineralized breccia along northerly range-front fault.
H31 Silicified iron-mineralized breccia in Pennsylvanian Bird Spring Formation along northerly range-front fault.

the Mormon Peak detachment, near the east end of the northern zone of metal enrichment. Sample 256, which contains 880 ppm zinc, is from limonitic breccia at the base of the Mormon Peak detachment southwest of the study area and within the southern zone of metal enrichment. Like antimony, mercury shows high values (>1 ppm) at the margin of the plug (samples 294, 1.29 ppm; 296, 2.23 ppm) west of the Iron Blossom prospect, and mercury is also enriched in iron-mineralized tuff at the Iron Blossom prospect (samples 289, 0.69 ppm; 290, 1.09 ppm) and in jasperized cherty dolomite of the Bird Spring Formation (sample 298, 0.50 ppm) northwest of the prospect. Tin was detected only in Proterozoic pegmatitic granite (samples 269, 20 ppm; 272, 30 ppm) at the west margin of the study area, and gold was detected only in copperrich mineralized rock (sample 281, 0.2 ppm) from the Whitmore mine. Anomalous but low amounts of tungsten and molybdenum (10–58 and 5–50 ppm, respectively) occur sporadically, but separately, where other metals are strongly enriched. Thorium, uranium, and thallium are found in anomalous but low amounts (15–25, 10–27, and 5–31 ppm, respectively) sporadically throughout the mineralized zones in the Mormon Mountains.

Mineral and Energy Resources

Mineralized Systems

The zones of anomalous metal enrichment in the study area, both in stream sediments and in rocks, are interpreted to represent three separate mineralized systems. The first is the broad southern zone of lead enrichment that includes two smaller areas of silver and copper enrichment, one at the northeast end of the lead zone at the east edge of the study area and one that extends northwestward from the vicinity of the Whitmore mine into the south end of the study area. Mineralization took place in breccia zones along both high- and low-angle faults, mostly in dolomitic rocks. Mineralized rocks are chiefly in the parautochthon below the Cretaceous Mormon thrust. However, anomalous lead in breccia along the Mormon Peak detachment indicates that mineralization there took place following detachment faulting, and that it is no older than Miocene. Also, the broad southern system is roughly centered on the apex of the domed Mormon Peak detachment.

A second mineralized system is the generally east-trending zone of anomalous metals at the north margin of the study area. In addition to enriched amounts of lead, silver, and copper, the zone contains high amounts of arsenic, antimony, and mercury, suggesting that it is a system distinct from the broad southern zone. Mineralized rocks are concentrated near or at the base of the Mormon Peak allochthon and along the Mormon Peak detachment. Minor mineralization took place in the Mormon thrust allochthon below the detachment near the east end of the mineralized zone, and in a young range-front fault near the west end of the mineralized zone. Taken altogether, the occurrences of mineralized rocks suggest that mineralization took place following emplacement of the Mormon Peak allochthon.

The small latite plug lying 0.5 mi northwest of the Iron Blossom prospect is centrally located within the northern mineralized system. The presence of anomalous enrichments of arsenic, antimony, and mercury at the margin of the plug suggests the plug as a source or conduit for mineralizing fluids that were responsible for mineral deposition at the prospect and elsewhere nearby. If so, apparently the plug was intruded following emplacement of the Mormon Peak allochthon, and the plug is therefore unrelated to the other volcanic rocks nearby.

A third mineralized system is manifested by enrichments of tungsten near the west-central part of the study area and of molybdenum in the east-central part of the study area. Tin is widely but sparsely distributed around the periphery of the Mormon Mountains, surrounding the study area. Much of the anomalous tin was derived from rocks that underlie the Mormon Peak detachment. However, some anomalous tin in the northwestern part of the Mormon Mountains was derived from the upper plate of the detachment, and it thus must have been introduced no earlier than emplacement of the Mormon Peak allochthon in Miocene time. The tungsten, molybdenum, and tin enrichments suggest a broad, zoned system seemingly unrelated to the other two systems just described. This third system may have been derived originally from a granite pluton of unknown age (postulated from geophysical evidence and the presence of mineralized rocks) underlying the Mormon Mountains.

Possible Metallic Mineral Deposit Types

The mineralized systems in and near the Mormon Mountains Wilderness Study Area may contain several metallic mineral deposit types. Only two deposits, those at the Whitmore mine and the Iron Blossom prospect, are known, but the geologic environment of the Mormon Mountains indicates the possibility of others.

The Whitmore mine is in the broad mineralized zone characterized by anomalous lead, which includes the south part of the study area and is centered on a domal structure inferred to be cored with intrusive rocks. The Whitmore deposit, characterized by copper-rich breccia that contains minor gold and silver, is localized on a low-angle fault beneath the Mormon thrust that places Cambrian dolostone upon Proterozoic rocks. Similar deposits could occur anywhere within the mineralized zone along this fault or other low-angle faults where brecciation has been extensive. Strongly brecciated high-angle faults are also possible sites for this type of mineral deposit. Perhaps carbonate layers in a favorable physical environment, similar or analogous to the medial limestone unit in the Bright Angel Shale or the Combined Metals Member of the Pioche Shale at Pioche (Tschanz and Pampeyan, 1970), have been extensively mineralized by lead, copper, zinc, and silver minerals along brecciated fault zones and in replacement mantos fed by solutions moving along permeable faults. At deeper levels in the mineralized system, within Proterozoic rocks and proximal to the inferred intrusive rocks believed to have been the cause of the widespread mineralization evidenced at the surface, stockwork or porphyry-type mineralization may have taken place. Deposits of this type may contain dominant copper, and minor amounts of gold may be present, particularly in contact (skarn or tactite) zones near intrusive rocks.

The southern area is judged to have a high mineral resource potential for deposits of copper, lead, zinc, silver, and (or) gold. The assignment is made with a certainty level of C because the available data show the presence of favorable geologic environments and evidence of resource formation, but the extent of the process(es) is unknown.

The Iron Blossom prospect is within the northern zone of anomalous lead, silver, copper, arsenic, and antimony, which extends into the north part of the study area and is centered on the latite plug. The deposit at the prospect is localized in brecciated, argillized, and silicified tuff in and above the Mormon Peak detachment, and it is characterized by anomalous iron, arsenic, antimony, and mercury. Although no gold was detected in mineralized samples collected at and near the prospect, gold is to be expected in disseminated deposits in such a geologic environment where the cited elements have been concentrated. Gold-bearing deposits of this character are possible in the volcanic rocks and in underlying carbonate rocks where permeable zones along fault breccias have allowed the flow of mineralizing solutions. Relatively high amounts of arsenic, antimony, and mercury at the margin of the plug suggest that the plug was a source or conduit for mineralizing solutions, and other mineralized zones may exist at deeper levels. If a stock underlies the plug and it was a source for mineralizing fluids, there may be tactite-type gold-rich copper-, lead-, and zinc-sulfide deposits in carbonate rocks at or near the stock contact. Stockwork or porphyry-type deposits enriched in copper or molybdenum also may occur in the vicinity of such a postulated stock.

The northern area is judged to have a high mineral resource potential for deposits that contain copper, lead, zinc, silver, gold, arsenic, and (or) antimony. The assignment is made with a certainty level of C because the available data show the presence of favorable geologic environments and evidence of resource formation, but the extent of the process(es) is unknown.

An area of anomalous amounts of antimony partly coincides with the northern mineralized system and extends southwestward a few miles beyond it. The area is considered to have moderate mineral resource potential for vein deposits of antimony. A certainty level of B is assigned because the available data suggest the presence of a favorable geologic environment, but there is no evidence that a mineralizing process occurred.

The sparsely mineralized zones of tungsten and molybdenum enrichment in and near the west- and east-central parts of the study area are suggestive of mineralization related to an underlying granitoid intrusive body. Their positions indicate that they are unrelated to either of the mineralized systems to the north and south; perhaps they are associated with a buried intrusive body also unrelated to those postulated for the other mineralized systems. Molybdenum-bearing stockwork or porphyry-type deposits and tungsten and (or) tin-bearing quartz veins are the types most likely to occur. If the postulated granitoid intrusive is at a level high enough to penetrate carbonate rocks overlying the Proterozoic basement, tungsten-bearing contact deposits may be present in the carbonate rocks. Disseminated scheelite (calcium tungstate) occurs in amphibolite near large bodies of tourmaline-muscovite pegmatite of Proterozoic age in the East Mormon Mountains a few miles east of the study area (Tschanz and Pampeyan, 1970). Similar deposits may underlie the study area.

The central areas are judged to have a moderate mineral resource potential for deposits of molybdenum, tungsten, and (or) tin. The assignment is made with a certainty level of B because the available data indicate the presence of favorable geologic environments, but there is no convincing evidence that mineralizing processes occurred.

A manganese-oxide vein occurs in a fault between Proterozoic rocks and Cambrian dolostone in the East Mormon Mountains (Tschanz and Pampeyan, 1970) a few miles east of the study area. Local concentrations of manganese (table 1) are found near the study area, but its mineral resource potential in the study area is considered to be low, with certainty level B, because there is no evidence of formation of manganese-bearing veins in the study area.

Other Mineral Deposit Types

Vermiculite was found in Proterozoic granitic pegmatite at the west edge of the study area (sample locality 269, pl. 1; Tschanz and Pampeyan, 1970). The deposit is small and it appears to be of poor quality. No other vermiculite is known to occur in the study area. The mineral resource potential for vermiculite in the study area is considered to be low, with certainty level D.

Thin barite veins occur in Proterozoic rocks in the East Mormon Mountains (Tschanz and Pampeyan, 1970) a few miles east of the study area. Moderate amounts of barium (1,000–1,500 ppm) are found in some mineralized samples collected near the study area (table 1). However, the mineral resource potential for barite is considered to be low, with certainty level B, because there is no evidence of formation of barite veins in the study area.

Energy Resources

According to Sandberg (1983), the Mormon Mountains have a moderate potential for oil and gas based on presence of suitable source rocks, maturation history, reservoir rocks, and traps. Also suggestive of moderate potential are indications of lack of high-temperature effects on some rocks and the presence of a dry hole with significant oil and gas shows drilled about 25 mi south of the Mormon Mountains. However, zones in the Mormon Mountains where intrusive igneous rocks are inferred and where hydrothermal alteration has been extensive have low potential for oil and gas, with certainty level B, as available information does not indicate where significant thermal or hydrothermal effects related to inferred igneous intrusions have occurred. The moderate energy resource potential assessment is made with a certainty level of B, as available information does not indicate the presence of oil or gas.

The study area has a low energy resource potential for coal and geothermal energy. No resources of coal or geothermal energy are known in the Mormon Mountains, nor is there any geologic evidence that they might be present. The assessment of low resource potential is thus made with a certainty level of B.

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APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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

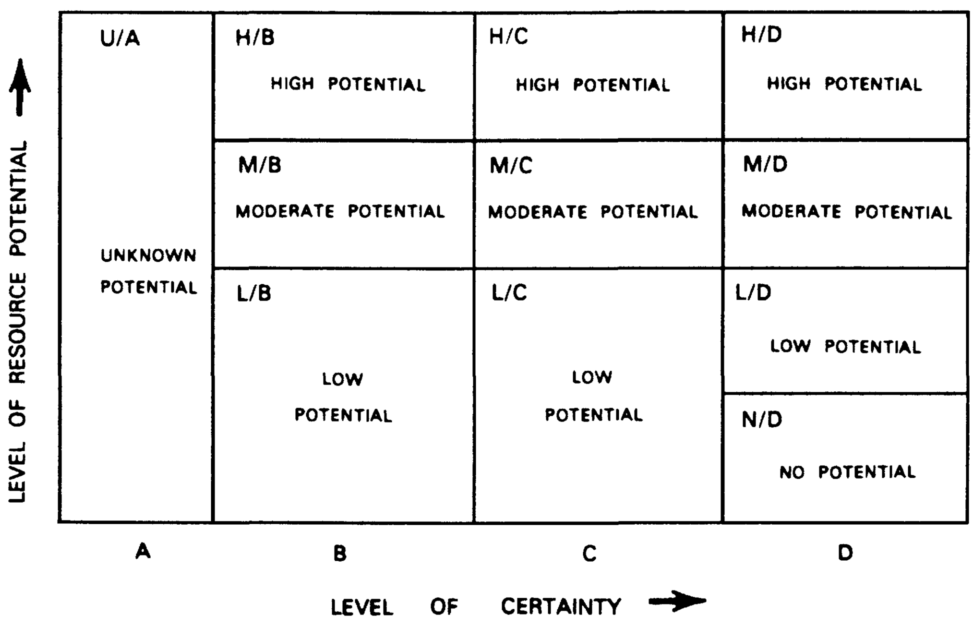
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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

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

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

Levels of Certainty



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

Abstracted with minor modifications from:

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RESOURCE / RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range	
	Measured	Indicated		Hypothetical (or)	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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