DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Mineral resources of the Mormon Mountains Wilderness Study Area and Addition, Lincoln and Clark Counties, Nevada

by

Daniel R. Shawe[1], H. Richard Blank, Jr.[1], Brian P. Wernicke[2], Gary J. Axen[3], Harlan N. Barton[1], Gordon W. Day[1], and David C. Scott[4]

(Supplement to U.S. Geological Survey Bulletin 1729-B, Mineral resources of the Mormon Mountains Wilderness Study Area, Lincoln County, Nevada, by Shawe, D.R., Blank, H.R., Jr., Wernicke, B.P., Axen, G.J., Barton, H.N., Day, G.W., and Rains, R.L.)

Open-File Report 90-0249

1990

[1]U.S. Geological Survey
Denver, CO 80225

[2]Department of Earth and Planetary Science
Harvard University,
Cambridge, MA 02138

[3]Department of Geology, Box 6030
Northern Arizona University
Flagstaff, AZ 86011

[4]U.S. Bureau of Mines
Denver, CO 80225

STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-979, 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 Wilderness Study Area and Addition (NV-050-161), Lincoln and Clark Counties, Nevada.

Contents

	Page
Abstract	1
Summary	1
Identified resources	3
Mineral resource potential	3
Introduction	6
Investigations by the U.S. Bureau of Mines	6
Investigations by the U.S. Geological Survey	7
Appraisal of identified resources	7
Mining history	7
Mines, prospects, and mineralized areas	7
Whitmore mine	8
Iron Blossom prospect	8
Hackberry Spring prospect	8
Southwest boundary of the study area	8
Limestone	9
Sand and gravel	9
Conclusions	9
Assessment of potential for undiscovered resources	10
Geology	10
Geologic setting	10
Description of rock units	10
Structure	12
Geophysics	12
Gravity data	13
Aeromagnetic data	13
Geochemical investigations and mineralized rocks	18
Sample collection and analytical methods	18
Stream-sediment samples	18
Rock samples	18
Mineral and energy resources	20
Mineralized systems	20
Possible metallic-mineral-deposit types	21
Other mineral-deposit types	22
Energy sources	23
References cited	24
Appendices	25

Illustrations

Page

Plate

1. Map showing mineral resource potential, generalized geology, and mine and prospect locations of the Mormon Mountains Wilderness Study Area, with addition, and vicinity, Lincoln and Clark Counties, Nevada . . . . In pocket

Figures

1. Index map of the Mormon Mountains Wilderness Study Area with addition, Lincoln and Clark Counties, Nevada 2
2. Summary map showing mineral resource potential and mine and prospect locations in the Mormon Mountains Wilderness Study Area, with addition, Nevada 4
3. Generalized geology of the Mormon Mountains Wilderness Study Area, with addition, and vicinity, Nevada 11
4. Complete Bouguer gravity anomaly map of the Mormon Mountains Wilderness Study Area, with addition, and vicinity, Nevada 14
5. Residual total-intensity aeromagnetic anomaly map of the Mormon Mountains Wilderness Study Area, with addition, and vicinity, Nevada 15
6. Residual upward-continued aeromagnetic anomaly map (reduced to the pole) of the Mormon Mountains Wilderness Study Area, with addition, and vicinity, Nevada 17

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, with addition), Nevada. The Mormon Mountains Wilderness Study Area (with addition) contains no identified resources; occurrence of commercial-grade limestone of undetermined extent and 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. A second zone in the northern 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

The Mormon Mountains Wilderness Study Area with addition (the study area) encompasses virtually the entire Mormon Mountains, in southeastern Lincoln County and northeastern Clark County, Nev., 50 mi (miles) northeast of Las Vegas (fig. 1). It is accessible by jeep roads from Meadow Valley Wash on the west side and from the Carp-Mormon Mesa road on the east side. Elevations in the study area range from about 2,200 ft (feet) at the 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 Precambrian crystalline rocks (see geologic time chart in Appendix) exposed in small patches at the west edge and in the south-central part of the mountains and in the southeastern part of the study area. Doming of the mountains probably was a result of intrusion of igneous rocks in Mesozoic-Tertiary time. Cambrian clastic marine sedimentary rocks lie in depositional contact upon crystalline rocks. A series of low-angle faults has episodically moved a thick section of Paleozoic marine sedimentary rocks, mostly carbonate strata, and thinner units of a variety of Mesozoic rocks, onto the older rocks. Tertiary volcanic rocks, in part also emplaced on low-angle faults, occur along the north margin of the Mormon Mountains. Younger high-angle faults of diverse orientations offset the rock formations and low-angle faults.

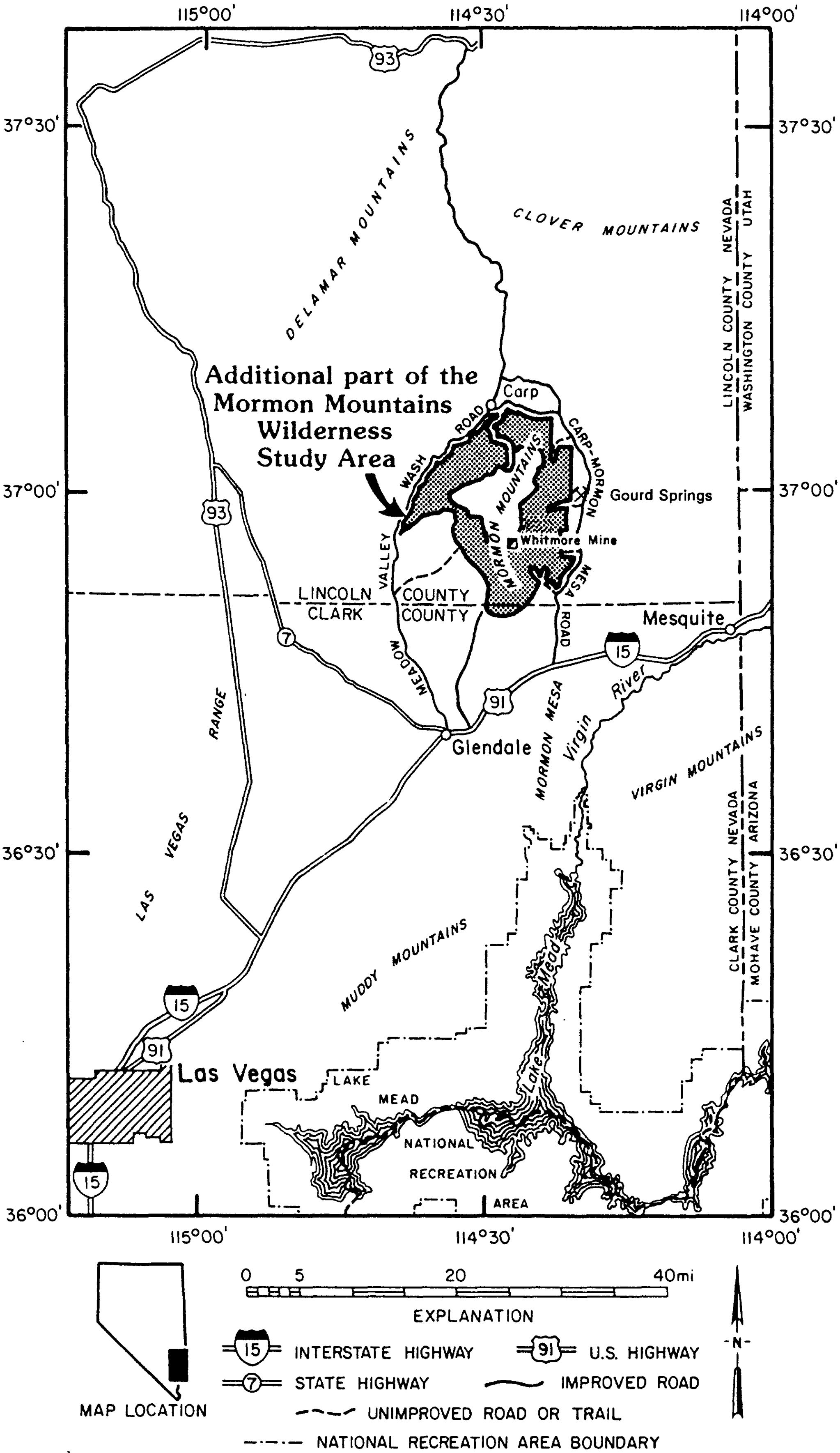


Figure 1. Index map of the Mormon Mountains Wilderness Study Area with addition, Lincoln and Clark Counties, Nevada.

Identified resources

A small amount of copper was produced from the Whitmore mine in the south-central part of the mountains (fig. 2). The Iron Blossom prospect, in the north part of the mountains, was probably developed for gold or silver. The study area has occurrences of commercial-grade limestone and deposits of sand and gravel; however, neither of these is classified as an identified resource.

Mineral resource potential

The Mormon Mountains Wilderness Study Area (with addition) 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 (commodities 1 and 2, respectively, as shown in fig. 2). Areas of high potential are defined by metal-enriched 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 by extensive hydrothermal systems that circulated metal-bearing fluids through faults and fractures. Hydrothermal fluids are interpreted to have had their sources in the postulated igneous intrusive rocks at depth, or they consisted of ground waters heated by the igneous intrusions.

A second zone in the northern part of the study area has moderate mineral resource potential for antimony (commodity 3, as shown in fig. 2). Two areas in the central part of the study area have moderate mineral resource potential for tungsten, molybdenum, and (or) tin (commodity 4, as shown in fig. 2). 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 environments.

The Mormon Mountains Wilderness Study Area has a moderate 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 in the vicinity of mineralized zones.

The study area has low mineral resource potential for manganese, barite, and vermiculite. Deposits of manganese and barite exist near the study area, but evidence is minimal for their occurrence within the study area. A deposit of vermiculite occurs in the study area, but it appears to be of poor quality. 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.

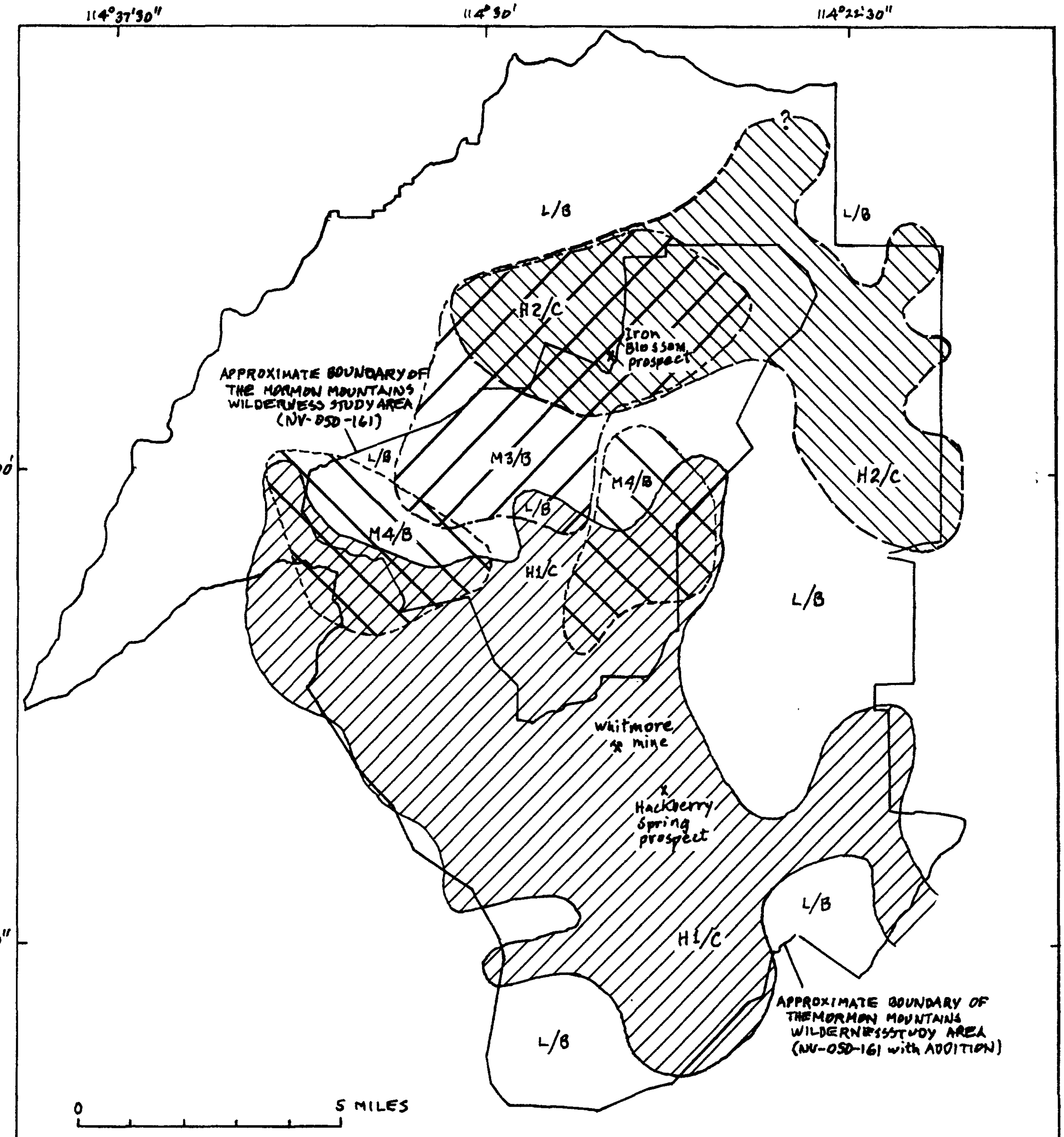


Figure 2. Summary map showing mineral resource potential and mine and prospect locations in the Momon Mountains Wilderness Study Area with addition, Nevada.

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

INTRODUCTION

The BLM (U.S. Bureau of Land Management) requested that 123,130 acres of the Mormon Mountains Wilderness Study Area (NV-050-161 with addition) be studied by the USBM and the USGS. This area encompasses virtually the entire Mormon Mountains and parts of surrounding alluvial fans and also includes a core area of 23,690 acres within the mountains that was evaluated earlier as a Wilderness Study Area (NV-050-161) by the USBM and the USGS, and previously reported on (Shawe and others, 1988). The 123,130-acre study area, referred to as the study area in this report, is in Lincoln and Clark Counties, Nev., 50 mi northeast of Las Vegas and just southeast of Carp (fig. 1). Access to the study area is by way of several unimproved jeep trails from Meadow Valley Wash and from the Carp-Mormon Mesa road (fig. 1).

Topographic relief in the study area is about 5,200 ft, ranging from 2,200 ft at the western boundary to 7,414 ft at Mormon Peak (pl. 1). Lower parts of the study area are sparsely covered with desert shrubs and Joshua trees. The higher elevations have pinyon pine and juniper trees along with some ponderosa pine near Mormon Peak. Davies, Horse, Wiregrass, and Hackberry Springs are perennial springs.

In this report the assessment of the earlier study area (NV-050-161) will be incorporated into the assessment of the enlarged study area (NV-050-161 with addition). The 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 USGS. Identified resources are classified according to the system of the USBM and USGS (1980), which is shown in the Appendix. 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 addition to the study area (NV-050-161) in July, 1989. During that time D.C. Scott, R.F. Kness, S.L. Korzeb, and M.E. Lane of the Bureau investigated mines, prospects, and mineralized areas to evaluate the quantity and quality of mineral reserves and resources. Forty-one samples were taken in or near the area. Results of the investigation have been summarized by Scott (1989).

No mineral resources were identified. Six areas in and within 1 mi of the addition contain mines and prospects (Scott, 1989, pl. 1). Copper-lead-zinc occurrences in brecciated quartz veins in faults at these mines and prospects have limited exposure and low metal concentrations, which precluded resource determination.

Limestone is present throughout most of the addition. Analytical data indicate some of the limestone is suitable for various commercial uses; however, the remote location of the limestone precludes any but local uses, and there is sufficient material outside the addition to supply those demands.

Sand and gravel are also present throughout the addition, although similar material is available outside the area, nearer to potential markets.

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 1979-1987. Detailed mapping was done at 1:12,000 and 1:24,000 scales. 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 sediment 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.

APPRAISAL OF IDENTIFIED RESOURCES

By David C. Scott
U.S. Bureau of Mines

Mining history

No mining districts are in the addition; the Viola (Pittsburg, Cherokee) district is about 10 mi north of the study area (fig. 2). The district was first prospected in the 1880's when the Cherokee vein was discovered; one carload of ore containing 1,400 oz silver per short ton reportedly was shipped. In 1958, Wells Cargo mined about 11,500 tons of fluorspar from the district. Mineral deposits in the district occur in faults and veins in Mississippian limestone near the base of overlying altered volcanic rocks. (See Tschanz and Pampeyan, 1970, p.160-165).

The Gourd Springs mining district, in the East Mormon Mountains (fig. 2), is about 5 mi east of the addition. In 1929, 60 tons of manganese was mined from probable Cambrian limestone in this district. The only other mining activity was in the 1940's when exploration for tungsten took place. Tungsten deposits occur in Precambrian rocks that have been overridden by a thrust plate of Pennsylvanian limestone. (See Tschanz and Pampeyan, 1970, p. 160-165; p.176).

In recent years, 300-400 placer claims have been staked on alluvial fans in the addition. As of August 1989, 39 placer and 58 lode mining claims were on file with the BLM (Scott, 1989, pl. 1) but no evidence of any current mining activity was found in the area.

Mines, prospects, and mineralized areas

The Whitmore mine and the Iron Blossom and Hackberry Spring prospects, all within the study area, were examined in detail; no resources were identified at these localities. Samples from within the study area were collected to evaluate the quality of the limestone. Detailed sample analyses

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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

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

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

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

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

Levels of Certainty

LEVEL OF RESOURCE POTENTIAL →

<table>
<tr><td rowspan="4">U/A

UNKNOWN POTENTIAL</td><td>H/B
HIGH POTENTIAL</td><td>H/C
HIGH POTENTIAL</td><td>H/D
HIGH POTENTIAL</td></tr>
<tr><td>M/B
MODERATE POTENTIAL</td><td>M/C
MODERATE POTENTIAL</td><td>M/D
MODERATE POTENTIAL</td></tr>
<tr><td rowspan="2">L/B
LOW POTENTIAL</td><td rowspan="2">L/C
LOW POTENTIAL</td><td>L/D
LOW POTENTIAL</td></tr>
<tr><td>N/D
NO POTENTIAL</td></tr>
<tr><td>A</td><td>B</td><td>C</td><td>D</td></tr>
</table>

LEVEL OF CERTAINTY →

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

Abstracted with minor modifications from:

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

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

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

are given in Rains (1986) and in Scott (1989). Thirty-one rock-chip samples collected in and near the addition to the study area were analyzed by fire assay/atomic absorption spectroscopy for gold and by inductively coupled plasma-atomic emission spectroscopy for a suite of 30 elements. Nine limestone and one gypsum sample were analyzed by whole-rock analysis to help determine their suitability for industrial use (see Scott, 1989).

Whitmore Mine

A cluster of workings in granite are within the south-central part of the addition at the Whitmore mine. Three short adits, totaling about 190 ft in length, five shafts (the deepest about 20 ft), and six prospect pits were found. The workings are in a 3-4 ft thick, N. 70 E.-striking, 25 NW.-dipping fault containing a brecciated quartz vein along a thrust fault (Olmore, 1971). The upper plate of the fault is composed of Cambrian dolostone and quartzite; the lower plate is composed of Precambrian undifferentiated metamorphic and granitic rocks. The fault can be traced intermittently for about 1,500 ft along strike. Limonite and malachite are common in the brecciated and fractured quartz vein.

Because the mine was sampled in detail by Rains (1986), only seven additional samples were taken to compare results with those previously obtained (Scott, 1989). Gold and silver were not detected except in a high-grade dump sample that contained 18 ppb Au and 5.8 ppm Ag. Copper concentrations in vein samples ranged from 8 ppm to 482 ppm; selected high-grade samples ranged from 1.23 percent to greater than 2.0 percent. Molybdenum concentrations in all the samples ranged from less than 1 ppm to 19 ppm; lead from less than 2 ppm to 168 ppm; and zinc from 5 ppm to 149 ppm (Scott, 1989). Concentrations of the metals in these samples are similar to those reported by Rains (1986, p. 17) and are well below ore grade.

Iron Blossom Prospect

A 10-ft shaft and two prospect pits were found at the Iron Blossom prospect inside the addition. These workings were investigated during the previous study by Rains (1986, p. 12). The workings are in a brecciated, argillized, and silicified tuff in and above the Mormon Peak detachment fault. Iron oxides occur along a silicified contact as much as 20 ft thick. Two samples were collected from the contact and one sample was taken from the dump (Scott, 1989). Copper, gold, lead, and silver concentrations were insignificant, but zinc ranged from 17 ppm in a sample from the contact to 0.3 percent in the dump sample. These zinc concentrations are below economic grades. Except for the elevated zinc concentration in the dump sample, these sample results are similar to the sample results of the investigation by Rains (1986, p. 15). The low metal concentrations and limited exposure of the zone preclude a resource estimation.

Hackberry Spring Prospect

One prospect pit and one adit (less than 40 ft long) were found within the addition about 1 mi southeast of the Whitmore mine, near Hackberry Spring. The workings are along a contact between Paleozoic limestone and shale. Three samples were taken from the contact (Scott, 1989). No gold or silver were detected, copper concentrations ranged from 18 ppm to 223 ppm, molybdenum concentrations ranged from 3 ppm to 4 ppm, lead concentrations ranged from 2 ppm to 21 ppm, and zinc concentrations ranged from 13 ppm to 37 ppm. The below-ore-grade metal concentrations suggest that no resources are present near the surface.

Southwest boundary of the study area

Samples collected from prospect pits, shallow shafts, and adits in faulted and mineralized Precambrian granite just outside the west and southwest boundaries of the study area contained anomalous amounts of silver, molybdenum, lead, zinc, and copper, but no detectible gold (Scott, 1989).

Limestone

Several random chip samples of limestone were collected and analyzed. Sample sites are shown on plate 1 of Shawe and others (1988) and on plate 1 of Scott (1989). Samples collected from the Mississippian Monte Cristo Limestone meet industry standards for cement manufacturing and for agricultural purposes. Other samples contain too much silica and magnesia to meet industry standards for cement manufacturing. Various industries have their own chemical requirements for limestone and would have to do detailed sampling of the limestone to determine its appropriateness for their specific uses. Currently no demand for limestone exists near the study area and similar limestone resources are present outside the area, nearer to population centers and more readily accessible for development.

Sand and gravel

Sand and gravel occur in the drainages and alluvial fans in the study area. The most common uses for these materials are as aggregate in concrete, road metal, and fill. Transportation costs limit the economic marketing range of these materials; therefore, only local uses such as road fill would be feasible for these commodities.

Conclusions

No metallic mineral resources were identified within the study area. Copper-lead-zinc occurrences were found in faults containing brecciated quartz veins. However, the occurrences are small and limited in extent, and metal concentrations are low.

Although oil and gas leases cover about 31 sections within the study area, no holes have been drilled. The USGS assessed the area as having a medium potential for oil and gas accumulation.

Limestone is present throughout most of the study area. Chemical analysis indicates that some limestone is suitable for several commercial uses; however, the remoteness of the area precludes any but local use, and local demand is presently lacking. Sand and gravel are present in drainages and alluvial fans in the study area; however, similar materials occur elsewhere, nearer to market places.

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 is shown on figure 3 and plate 1.

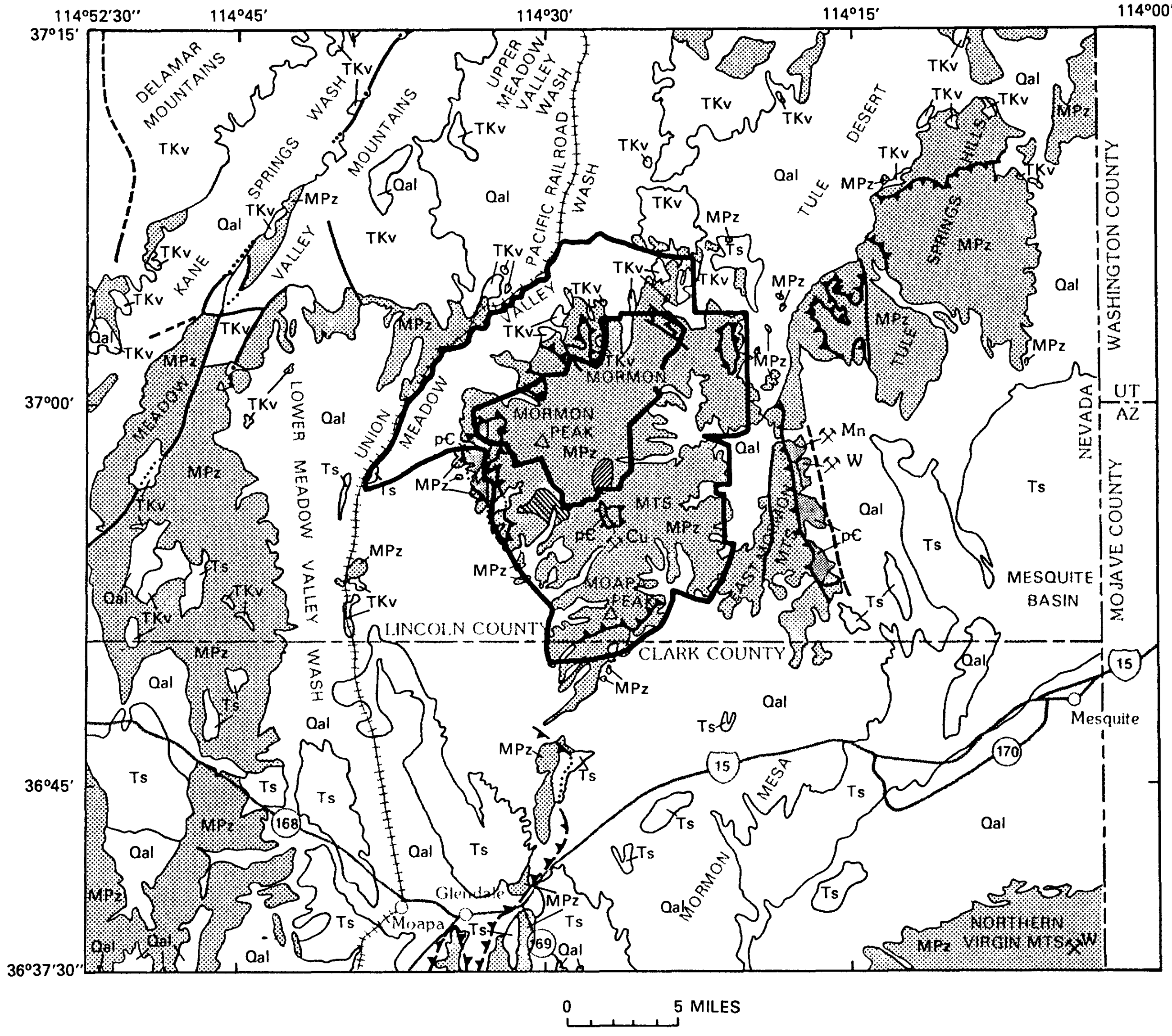
Geologic setting

The Mormon Mountains Wilderness Study Area lies near the south end of the Nevada-Utah section of the Basin-range tectonic province. The study area has experienced a long geologic history that included formation of an Early Proterozoic "basement complex" consisting of metamorphic and igneous rocks, erosion of that complex, deposition of Late Proterozoic and Paleozoic marine sedimentary rocks upon the eroded surface of the basement complex, and deformation of the sedimentary rocks during late Paleozoic time. Subsequently, during the Mesozoic Era, additional marine and continental sedimentary rocks were deposited in the region, and they too were deformed and igneous rocks intruded during an orogenic episode. During Cenozoic time deformation and extensive volcanic activity took place, followed by tectonism that formed the present block-faulted mountain ranges that now define the Basin-range 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); Paleozoic rocks undivided (unit Pz); Cambrian clastic rocks (unit Cc); Cambrian dolostone (unit Cd); Ordovician to Mississippian dolostone and limestone (unit MOd); Permian, Pennsylvanian, and Mississippian Bird Spring Formation (unit PMb); Permian "redbeds" (unit Pr); Permian Toroweap Formation and Kaibab Limestone (unit Pk); Triassic rocks undivided (unit ₮u); Tertiary volcanic and sedimentary rocks (unit Tv); older Quaternary alluvium (unit Qao); 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 and igneous rocks on a surface of low relief. The clastic rocks (Cc) 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 (Cd) 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 (MOd) 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 Mississippian, Pennsylvanian, and Permian Bird Spring Formation (PMb) consisting mostly of cherty limestone overlies the Monte Cristo Limestone. Overlying these rocks are clastic Permian "redbeds" (Pr). These rocks are overlain by the Permian Toroweap Formation (partly evaporites) and



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, and of addition

W Mine—Showing principal commodity extracted: Cu, copper; Mn, manganese; W, tungsten

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

limestone of the Kaibab Formation (Pk). Above these rocks are Triassic strata (T u) consisting of the Virgin Limestone with a lower redbed-conglomerate unit, the Schnabkaib Member of the Moenkopi Formation, and the mostly clastic Chinle Formation. Tertiary volcanic rocks (Tv) that unconformably overlie older rocks in and near the north part of the study area are lava flows and breccias of rhyolitic, dacitic, and basaltic composition with minor volcaniclastic interbeds, and silicic ash-flow tuffs. Tertiary rocks in the south part of the study area consist successively of part of the Overton Conglomerate Member of the Baseline Sandstone, lacustrine limestone, and the clastic Muddy Creek Formation. A small intrusive latite plug lies 0.5 mi northwest of the Iron Blossom prospect. Older Quaternary alluvium (Qao) is distinguished only near the northwest margin of the study area. Quaternary alluvium and talus deposits unconformably overlie the older deposits (Qa).

Structure

Rocks in the Mormon Mountains Wilderness Study Area 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 (lowest unit) 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, widely exposed in the study area, that has moved overlying rocks (referred to here as the "Mormon thrust plate") perhaps 7-17 mi eastward or northeastward. A similar fault, the Glendale thrust fault, is exposed locally in the south part of the study area. The generally east-directed overthrusting along the Mormon and Glendale faults took place during the Cretaceous Sevier mountain building event.

The Mormon Peak detachment, a yet higher low-angle fault, 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 Mountain (Wernicke, 1982), indicating that the surface of the detachment has been significantly domed since Miocene emplacement of the allochthon. The center of the dome (labelled allochthon dome on fig. 3, and cross section, pl. 1) lies near 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 of which are older than the Mormon Peak detachment and others are younger than the Mormon Peak detachment.

Geophysics

Regional gravity and aeromagnetic data were compiled as an aid in assessing the mineral resource potential of the study area. Sources of data are given in Shawe and others (1988).

Gravity data

A complete Bouguer gravity anomaly map of the Mormon Mountains Wilderness Study Area and vicinity is shown on figure 4. The reduction density was 2.67 g/cm^3 and terrain corrections were carried out to a radius of 167 km from each station using a 15 in. digital terrain grid. The Mormon Mountains, East Mormon Mountains, and Tule Spring Hills are located on a regional Bouguer anomaly high (fig. 4), here interpreted as the expression of an extensive elevated region of relatively dense Proterozoic crystalline basement, with its cover of highly tectonized and only slightly less dense Paleozoic carbonate strata.

This regional gravity high has a number of local maxima and minima. Local anomaly relief may result from any or all of the following: structural relief on the regionally elevated basement surface, intrabasement density contrasts, and variations in mean density of the suprajacent sedimentary rocks. An additional factor may be variations in mean density of the topography with respect to the standard reduction density.

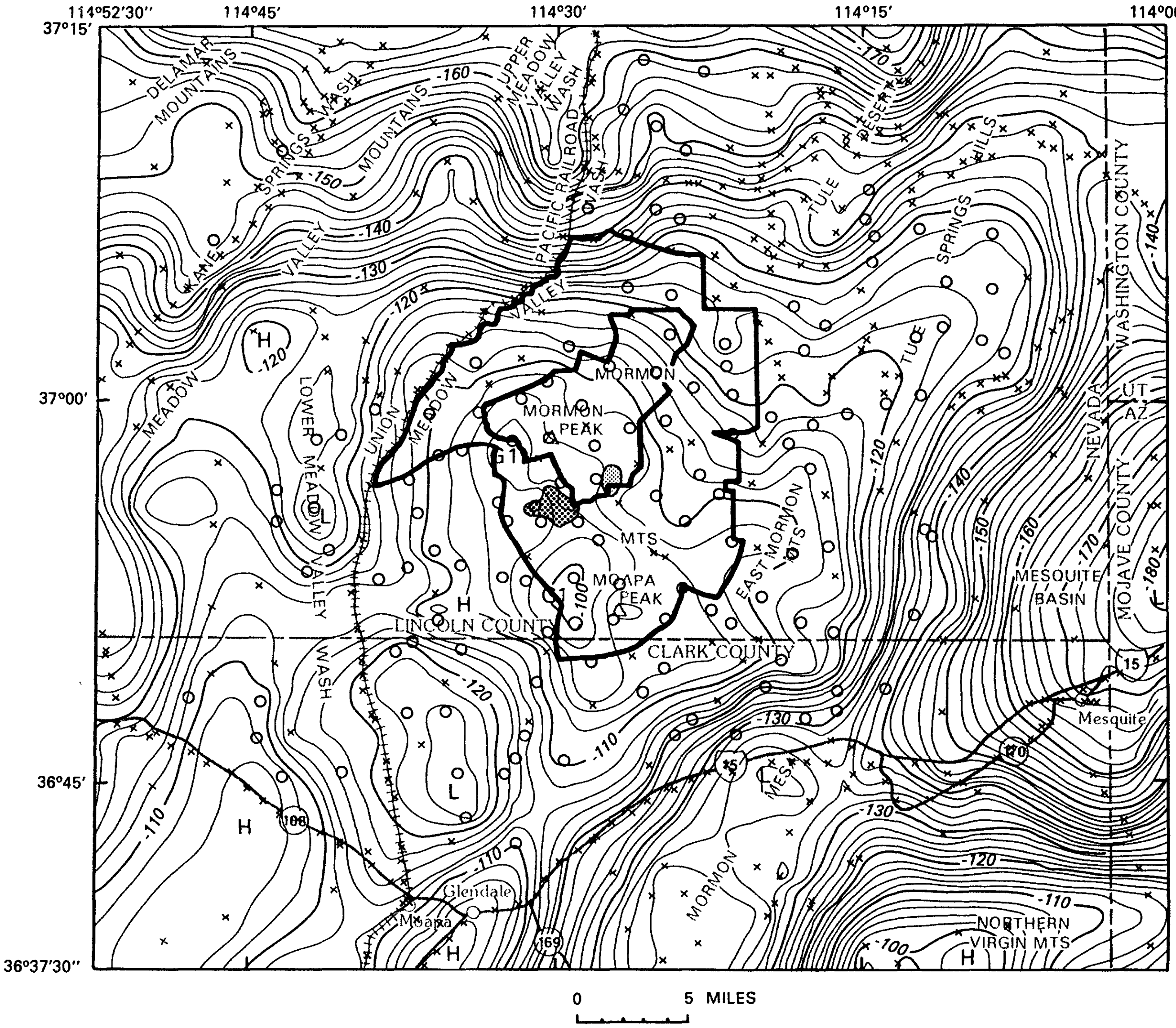
The anomaly field of the Mormon Mountains consists for the most part of a broad "bulge" superposed on the regional high. The bulge culminates in two crests, labeled G1 and G2, near Mormon Peak and Moapa Peak, respectively (see fig. 4). The northern part (G1 and vicinity) has a partly developed subcircular outline, includes areas of outcrop of crystalline rock west of Mormon Peak and at the Whitmore mine, encompasses domal structures on the Tapeats Sandstone and Mormon Peak detachment fault (see fig. 4), and closely corresponds to a subcircular positive aeromagnetic anomaly. From these relations we surmise that the anomalous gravity field in the vicinity of G1 results from a domal bulge on the surface of the basement. The southern part of the G1-G2 gravity high, cresting at G2, may also reflect elevated basement but extends south beyond the limits of the aeromagnetic anomaly, suggesting significant contributions from the non-magnetic carbonate rocks.

The inferred basement dome underlies most of the Mormon Mountains. Like the mapped domal configuration of the Tapeats Sandstone and Mormon Peak detachment fault, it is more or less central to the collective systems of hydrothermal mineralization delineated in the course of the present investigation.

Aeromagnetic data

Figure 5 shows the residual total-intensity magnetic field for the same area as that in figure 4 after removal of the International Geomagnetic Reference Field (IGRF). The data are for a drape elevation of 1,000 ft above terrain, the flight elevation for coverage south of lat. 37°00′ N., whereas coverage north of this latitude was obtained at a constant barometric altitude of 9,000 ft above sea level. The anomalous field is not well depicted near the merge boundary.

All of the Paleozoic miogeoclinal rocks are expected to have a very weak magnetization, and thus the anomalies seen on figure 5 must arise from sources in the crystalline basement and (or) from intrusive and volcanic rocks of Mesozoic or younger age. The region of elevated basement inferred from gravity data does not have a corresponding aeromagnetic expression, mainly because the Cenozoic basin deposits are essentially non-magnetic and therefore cannot be distinguished magnetically from the Paleozoic rocks. However, a prominent positive anomaly is associated with the Mormon Mountains. Because



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**

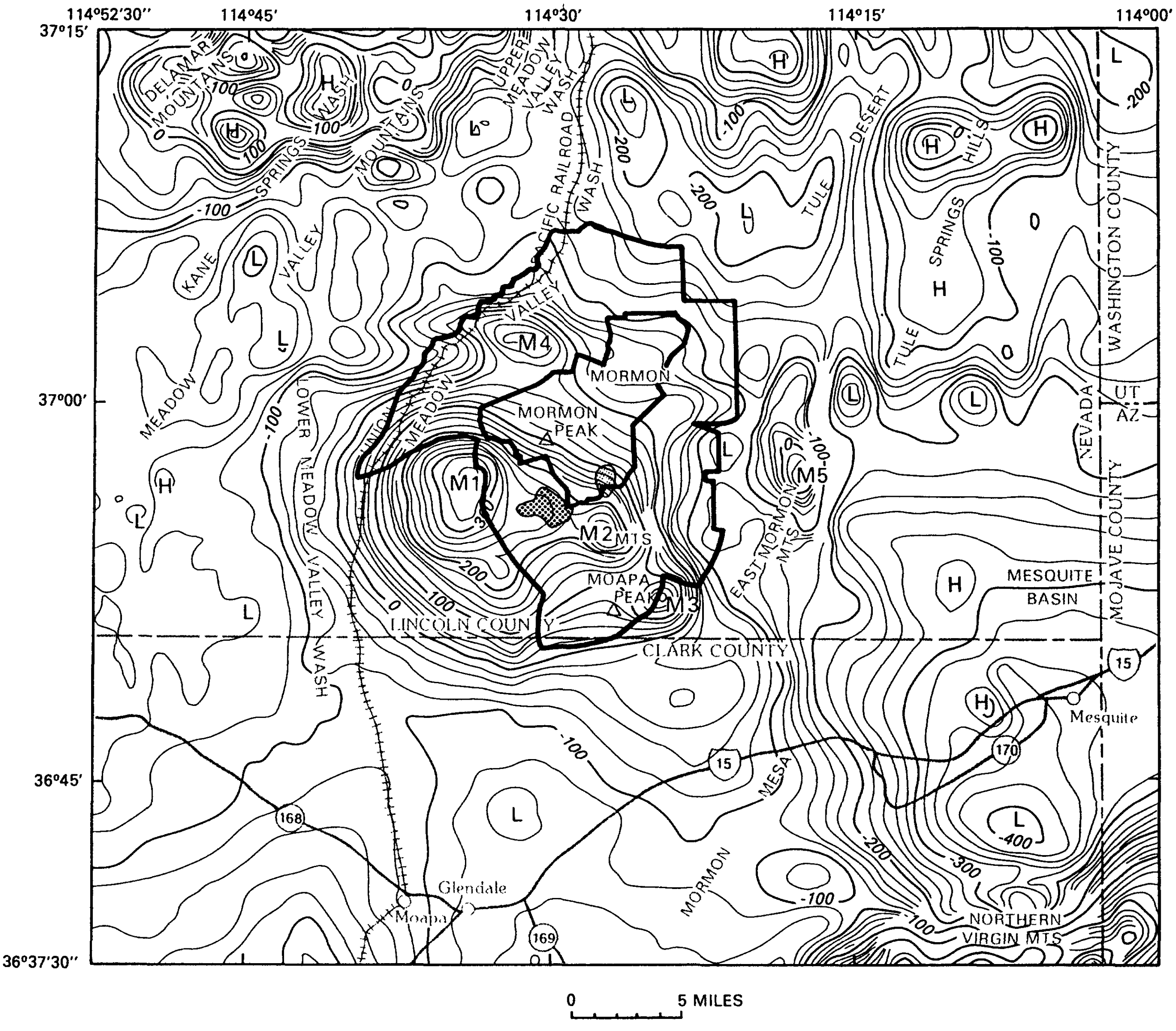
o **This study**

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

Approximate crest of dome on Tapeats Sandstone (autochthon dome)

Approximate boundries of Mormon Mountains Wilderness Study Area, and of addition

Figure 4. Complete Bouguer gravity anomaly map of the Mormon Mountains Wilderness Study Area, with addition, 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 boundries of Mormon Mountains Wilderness Study Area, and of addition

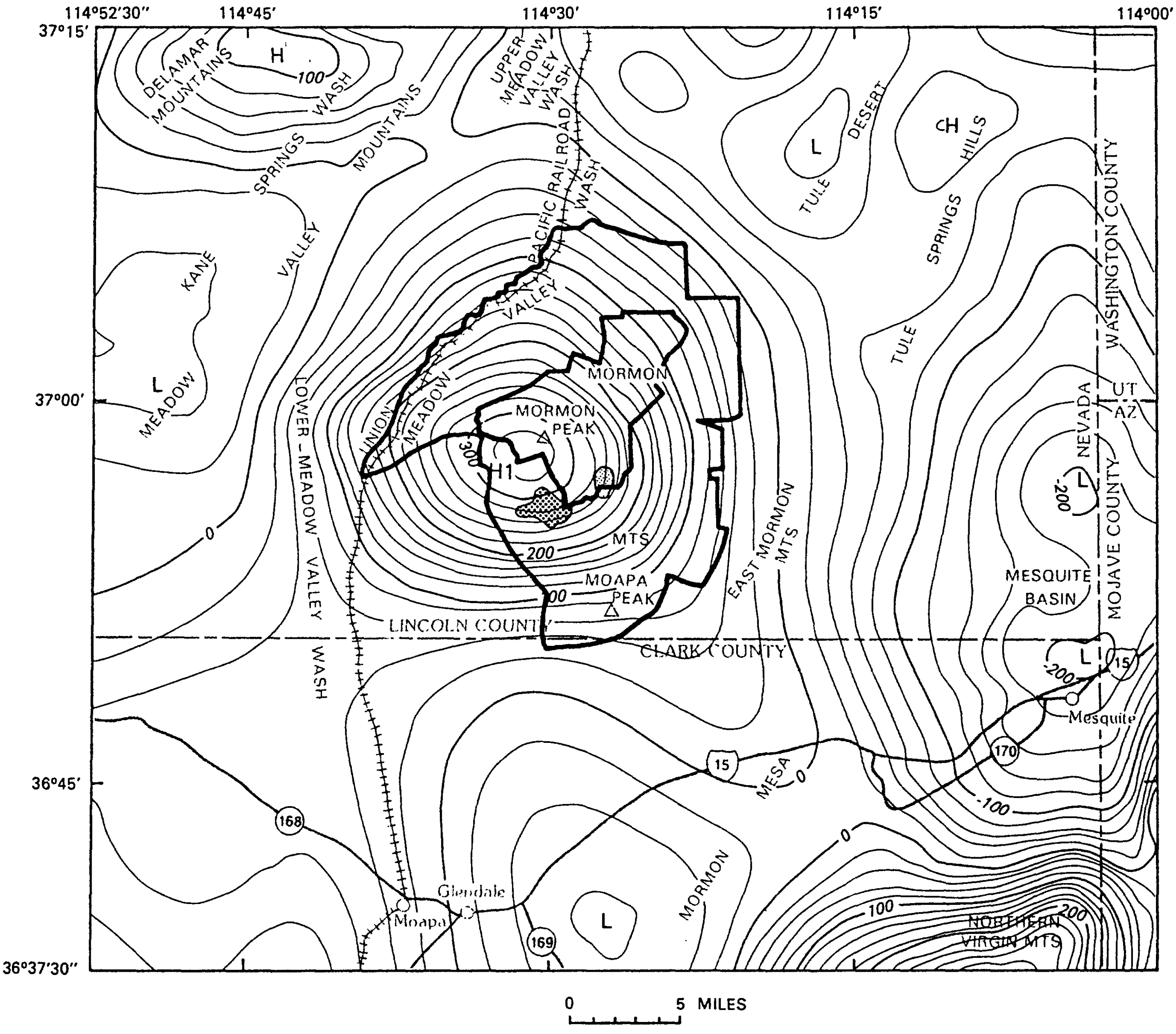
Figure 5. Residual total-intensity aeromagnetic anomaly map of the Mormon Mountains Wilderness Study Area, with addition, and vicinity, Nevada.

of the inclination and declination of the Earth's main field in this region, anomaly maxima generally do not directly overlie their respective source bodies but are displaced to the southwest of them, and are accompanied by weaker minima on the northeast sides. The Mormon Mountains anomaly is offset somewhat to the southwest of the center of the range, but otherwise closely corresponds to the subcircular gravity feature with crest at G1 (fig. 4). Clusters of short-wavelength aeromagnetic anomalies to the north of the Mormon Mountains (fig. 5) are produced by Tertiary volcanic rocks, while strong anomalies in the southeast corner of the map are due to sources in the Proterozoic crystalline complex of the northern Virgin Mountains.

Three local maxima (M1, M2, and M3, fig. 5) define a northwest-trending crest of the Mormon Mountains aeromagnetic anomaly. All lie within or partly within the study area. The highest in amplitude (M1) occurs over exposures of basement rock just west of the crest of the Tapeats dome, a weaker maximum (M2) is associated with basement exposed in the vicinity of the Whitmore mine south of the crest of the dome on the Mormon Peak detachment fault, and the third and weakest maximum (M3) occurs over alluvium near the mouth of a wash at the southeast margin of the mountains. M3 probably is due to near-surface crystalline rock beneath the alluvium. An east-trending high (M4) on the north flank of the mountains may be an artifact of the data-merging process. On the other hand, M4 may represent 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. A north-trending high (M5) similar in shape and amplitude to M4 is produced by basement rocks of the East Mormon Mountains.

Figure 6 shows the residual aeromagnetic field continued upward to a uniform elevation of 12,500 ft and reduced to the pole. The upward-continuation process suppresses the effect of shallow sources relative to that of deeper sources; reduction to the pole simulates vertical magnetization, on the assumption that all sources are magnetized in the direction of the present Earth's field. The result is the transformation of the Mormon Mountains positive anomaly into a "bulls-eye" feature having a smoother and more symmetrical geometry and a single maximum located approximately over Mormon Peak. This anomaly is almost exactly coincident with the subcircular part of the gravity anomaly, as pointed out above. All of the local maxima (M1-M5) were eliminated by the upward-continuation process. Similar modeling of the gravity and comparison with the upward-continued aeromagnetic anomaly shows that the two sets of data are in reasonable agreement with the fields produced by a uniform dome 20-25 mi wide having an amplitude about 3 mi, which reaches the ground surface at the two places where crystalline basement crops out. Contrary to a previous estimate (Shawe and others, 1988, p. B11), it is possible to match the observed anomalies by the effect of basement relief alone; the data allow but do not require the presence of additional sources.

Whatever the exact shape of the Mormon Mountains basement uplift, its size and domal symmetry together with its positive topographic and gravity anomaly signatures argue against an isostatic origin. That is, it probably was not formed as a result of isostatic accommodation to tectonic denudation during regional extension. A more satisfactory explanation for the uplift seems to us to be emplacement of an intrusive body or bodies beneath the dome in middle Miocene time, which would also have provided a heat source for the hydrothermal system(s). Lack of unequivocal potential-field evidence of such a body or bodies is readily explained by similarity of bulk physical properties of intrusion(s) and host, and (or) great depth of burial.



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 boundries of Mormon Mountains Wilderness Study Area, and of addition

Figure 6. Residual upward-continued aeromagnetic anomaly map (reduced to the pole) of the Mormon Mountains Wilderness Study Area, with addition, and vicinity, Nevada.

Geochemical investigations and mineralized rocks

Sample collection and analytical methods

Stream-sediment samples were collected from about 200 sites throughout the study area and were prepared as heavy-mineral concentrates and as minus-10-mesh composited samples. Twenty-five rock samples were collected in a 1983 reconnaissance by Barton and Day (1984), and an additional 90 were collected by Shawe and J.B. Hansen in November 1985. Further details on sampling and on analytical methods used to determine element contents of the samples were presented by Shawe and others (1988).

Stream-sediment samples

Lead is anomalous in a broad zone that includes much of the southern two-thirds of the Mormon Mountains, as well as in smaller areas at the north and northeastern edges of the mountains. Values range from 200 to 30,000 ppm (parts per million) lead in heavy mineral concentrates. Locally in the lead-enriched zones anomalous silver values range from 5 to 20 ppm. Copper is more sporadically distributed than is lead, but it occurs in anomalous amounts ranging from 50 to 300 ppm in heavy mineral concentrates throughout the study area. Anomalous samples are most abundant and have highest values in heavy mineral concentrates as well as 100-150 ppm Cu in stream-sediment samples locally in the northern half of the Mormon Mountains. 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 in the west-central part of the Mormon Mountains, and a zone of molybdenum enrichment (50-100 ppm in heavy-mineral concentrates) lies in the central part of the Mormon Mountains. Surrounding this 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 throughout the Mormon Mountains are related generally to the broad concentrations of lead in the southern two-thirds of the mountains and at the northern and northeastern margins of the mountains. Zinc in these areas is most abundant in the eastern part of the mountains where anomalous values range from 500 to 5,000 ppm in heavy-mineral concentrates.

Rock samples

Analytical data for mineralized samples collected within the study area were presented by Shawe and others (1988). The data 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 stream-sediment samples. Anomalous lead values (150-1,500 ppm) were detected in samples collected from iron-oxide-rich zones (gossans) in dolostone in the southern zone of anomalous lead in stream sediments . One sample 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 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 that form a stockwork at the Iron Blossom prospect (the stockwork is centered in the west part of the northern zone of anomalous metals) and (2) an iron-mineralized quartz pod in Proterozoic amphibolite near the west margin of the Mormon Mountains. Anomalous arsenic (200-6,300 ppm) was detected in more than half the samples collected in the study area; arsenic 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. 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. 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 a mineralized, sheared, and brecciated north-trending fault in Cambrian dolostone west of the Whitmore mine, and 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 and in jasperized cherty dolostone and limestone of the Pennsylvanian and Permian Bird Spring Formation 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 in the 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. 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. A sample of a brown algal chert layer in Cambrian dolostone in the upper plate of the Mormon thrust fault and beneath the Mormon Peak detachment, near the east end of the northern zone of metal enrichment, contains anomalous zinc. Limonitic breccia at the base of the Mormon Peak detachment in the southwest part of the Mormon Mountains within the southern zone of metal enrichment also is enriched in zinc. Like antimony, mercury shows high values at the margin of the plug west of the Iron Blossom prospect, and mercury is also enriched in iron-mineralized tuff at the Iron Blossom prospect and in jasperized cherty dolostone of the Bird Spring Formation northwest of the prospect. Tin in low amounts was detected only in Proterozoic pegmatitic granite at the west margin of the mountains, and gold was detected (0.2 ppm) only in copper-rich mineralized rock 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 a central smaller area of silver and copper enrichment near and just north of the Whitmore mine. 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 subsequent to detachment faulting, and that it is no older than Miocene. Also, the broad southern system is centered roughly on the apex of the domed Mormon Peak detachment.

A second mineralized system is the generally east- to southeast-trending zone of anomalous metals at the north margin of the Mormon Mountains. In addition to enriched amounts of lead, silver, and copper, the zone contains high amounts of arsenic, antimony, and mercury, as well as locally anomalous molybdenum, 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 middle 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 rock 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 western part of 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 in the west-central part of the Mormon Mountains and of molybdenum in the central part of the mountains. Tin is widely but sparsely distributed around the periphery of the Mormon Mountains. 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 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 is centered on a domal structure inferred to be cored with intrusive rocks. This 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. If porphyry deposits are present, molybdenum as well as copper may be present in significant amounts. The potential 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, antimony, and molybdenum, the western part of which 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 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 if 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, molybdenum, 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 the west-central and central parts of the Mormon Mountains are suggestive of mineralization related to underlying granitoid intrusive bodies. The position of the zone of tungsten mineralization indicates that it is unrelated to either of the mineralized systems to the north and south; perhaps it is associated with a buried intrusive body also unrelated to those postulated for the other mineralized systems. The molybdenum mineralization may be in part related to the northern and southern systems just described, or like tungsten, it may be associated with an unrelated granitoid intrusive. 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 intrusives are at a level high enough to penetrate carbonate rocks overlying the Proterozoic basement, tungsten-bearing contact deposits may be present in carbonate rocks. Disseminated scheelite (calcium tungstate) occurs in amphibolite near large bodies of tourmaline-muscovite pegmatite of Proterozoic age in the East Mormon Mountains just 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 Pampayen, 1970) just east of the study area. Local concentrations of manganese are found in the study area, but its mineral potential 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 Mormon Mountains (sample locality 269, Shawe and others, 1988, 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) at the east margin of the study area. Moderate amounts of barium (1,000-1,500 ppm) are found in some mineralized samples collected in the study area. 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 sources

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.

REFERENCES CITED

Barton, H.N., and Day, G.W., 1984, Reconnaissance geochemistry of the Mormon Mountains--Bureau of Land Management Wilderness Study Area (NV 050-0161), Lincoln County, Nevada: U.S. Geological Survey Open-File Report 84-361, 47 p.

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

Longwell, C.R., Pampeyan, E.H., Bowyer, Ben, and Roberts, R.J., 1979, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines and Geology Bulletin 62, 218 p.

Olmore, S.D., 1971, Style and evolution of thrusts in the region of the Mormon Mountains, Nevada: Salt Lake City, Utah, University of Utah, Ph.D. thesis, 268 p.

Rains, R.L., 1986, Mineral resources of the Mormon Mountains study area, Lincoln County, Nevada: U.S. Bureau of Mines Open File Report MLA 69-86, 18 p.

Sandberg, C.A., 1983, Petroleum potential of wilderness lands in Nevada, in Miller, B.M., ed., Petroleum potential of wilderness lands in the Western United States: U.S. Geological Survey Circular 902-A, p. H1-H11.

Scott, D.C, 1989, Mineral investigations of an additional part of the Mormon Mountains Wilderness Study Area (NV-050-161), Clark and Lincoln Counties, Nevada: U.S. Bureau of Mines Open File Report MLA 40-89, 17 p.

Shawe, D.R., Blank, H.R., Jr., Wernicke, B.P., Axen, G.J., Barton, H.N., Day, G.W., and Rains, R.L., 1988, Mineral Resources of the Mormon Mountains Wilderness Study Area, Lincoln County, Nevada: U.S. Geological Survey Bulletin 1729-B, 18 p.

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. 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.

Wernicke, B.P., 1982, Geology of the central Mormon Mountains, Lincoln County, Nevada, Chapter IV in Processes of extensional tectonics: Cambridge, Mass., Massachusetts Institute of Technology, Ph.D. thesis, 170 p.

APPENDICES

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.

☆U.S. GOVERNMENT PRINTING OFFICE:1988- 573-047/66099

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 McKelvey, 1972, Mineral resource estimates and public policy: American Scientist, v.60, p.32-40, and 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.