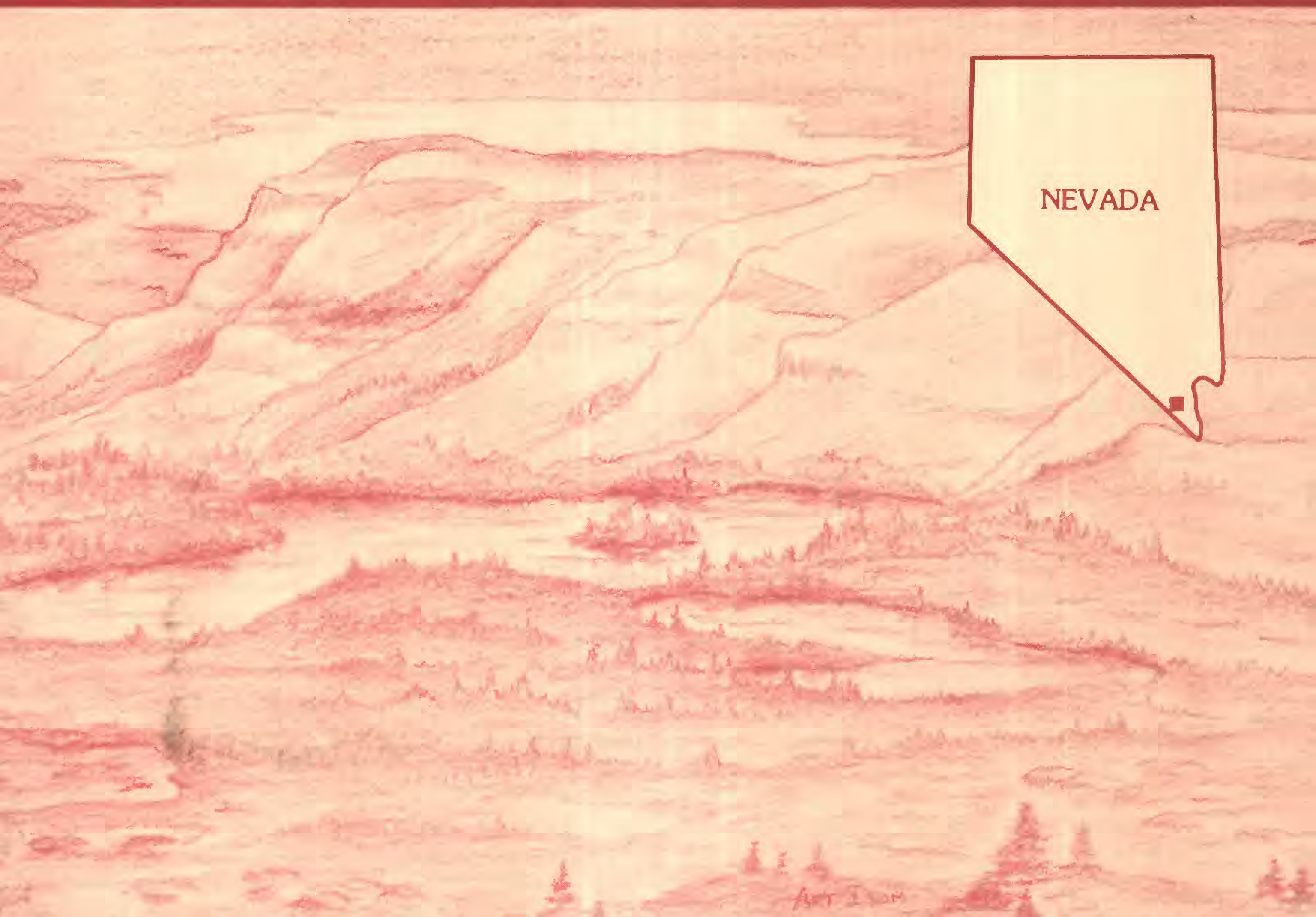
Mineral Resources of the South McCullough Mountains Wilderness Study Area, Clark County, Nevada

U.S. GEOLOGICAL SURVEY BULLETIN 1730–C



Chapter C

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U.S. GEOLOGICAL SURVEY BULLETIN 1730

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—SOUTHERN NEVADA

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

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

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of a part of the South McCullough Mountains Wilderness Study Area (NV–050–435), Clark County, Nevada.

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[Plate is in pocket]

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Mineral Resources of the South McCullough Mountains Wilderness Study Area, Clark County, Nevada

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ABSTRACT

The South McCullough Mountains Wilderness Study Area includes 19,558 acres and contains no identified mineral resources and has no areas of high mineral resource potential. Five areas that make up 20 percent of the study area have a moderate potential either for undiscovered silver, gold, lead, copper, and zinc resources in small vein deposits, for lanthanum and other rare-earth elements, uranium, thorium, and niobium in medium-size carbonatite bodies and dikes, for tungsten and copper in small to medium-size vein deposits, or for silver and gold in small vein or breccia-pipe deposits. Six areas that make up 24 percent of the study area have an unknown resource potential either for gold, silver, lead, and copper in small vein deposits, for gold, silver, lead, zinc, copper, and arsenic in small vein deposits or small to medium-size breccia-pipe deposits, for lanthanum and other rare-earth elements, uranium, thorium, and niobium in medium-size carbonatite bodies and dikes, or for tungsten and copper in small vein deposits. The designation of unknown resource potential for these areas is used because available geochemical data are not adequate to assign low, moderate, or high levels of resource potential. Four areas that make up 7 percent of the study area have a low resource potential either for tin, for tungsten and copper, or for copper, gold, silver, and arsenic in small vein deposits. The remaining 30 percent of the study area (areas covered by relatively young volcanic rocks are omitted) has a low resource potential for zinc, copper, silver, and gold in medium-size to small stratabound deposits, or for niobium, tantalum, uranium, rare-earth elements, and thorium in small pegmatite bodies, and an unknown potential for gold and silver in small to medium-size breccia pipes. The entire study area has no resource potential for oil and gas and coal, as well as a low resource potential for these nonmetallic commmodities: dimension stone; sand and gravel; pegmatite minerals such as feldspar and mica; and geothermal resources. These conclusions are based on field studies done in 1985 and 1986.

SUMMARY

As requested by the U.S. Bureau of Land Management, the U.S. Geological Survey and the U.S. Bureau of Mines studied 19,558 acres of the South McCullough Mountains Wilderness Study Area (NV–050–435). In this report the area studied is referred to as the "study area." The study area, south of Las Vegas, Nev., and east of Mountain Pass, Calif., is in the McCullough Range, a north-trending range in southern Clark County (fig. 1). The area is accessible by trails leading away from high-voltage transmission lines between Boulder City, Nev., Nevada Highway 68, and Interstate Highway 15. Vegetation is typical of the eastern Mojave Desert. Terrain within the study area is rugged, ranging from elevations of 3,200 ft (feet) to 7,026 ft.

The McCullough Range is in the Basin and Range physiographic province, a geologic terrane characterized by linear mountain chains flanked by basins. The oldest

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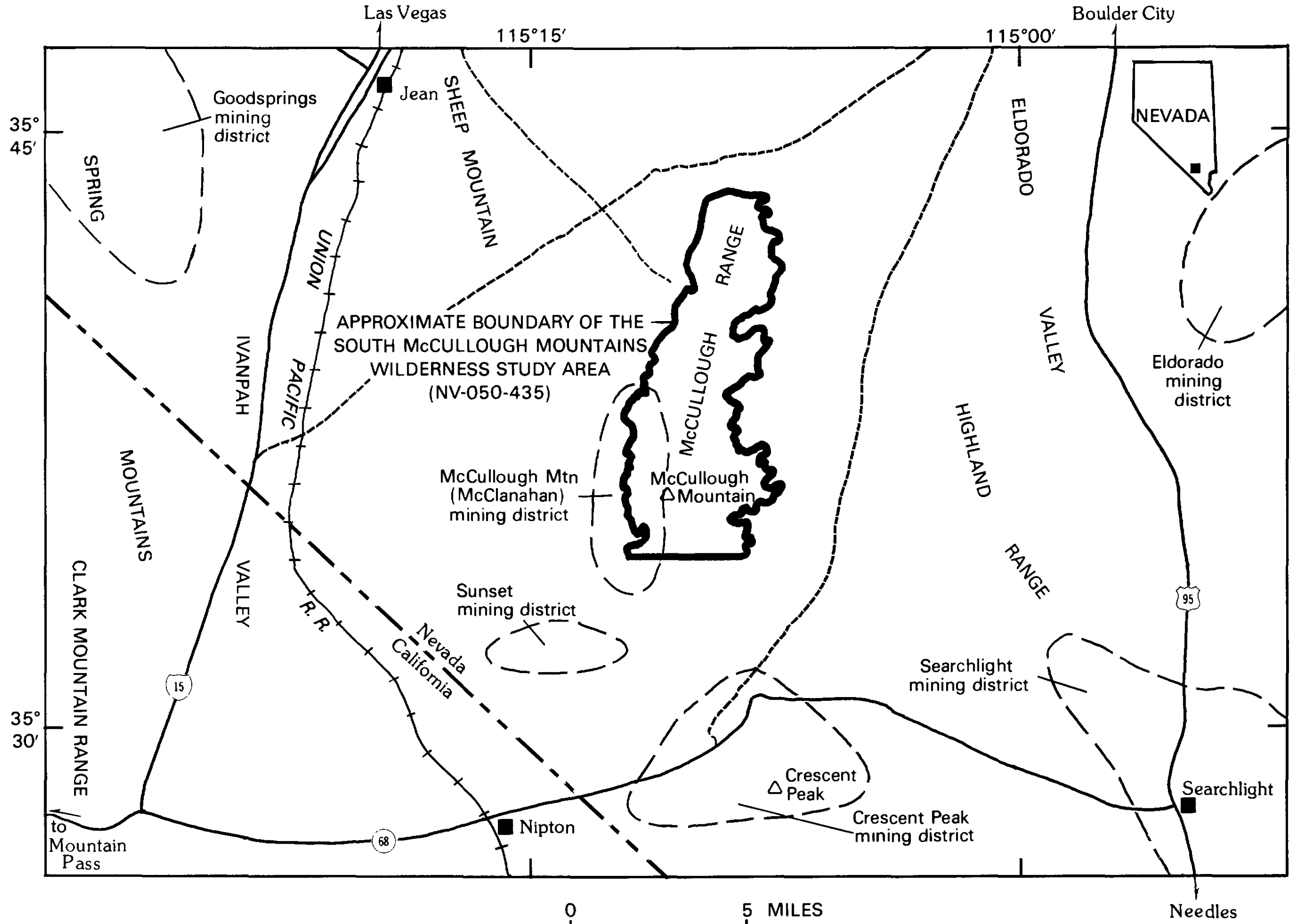


Figure 1. Index map showing location of the South McCullough Mountains Wilderness Study Area, Clark County, Nev. Location of McCullough Mountain (McClanahan) mining district from Close (1987).

geologic events (those happening more than 1,000 million years ago (1,000 Ma)) may have controlled most of the emplacement of mineral deposits of the area. Those events include emplacement of igneous bodies, shearing, and metamorphism during which quartz veins, pegmatite bodies, and possible carbonatite deposits were emplaced. Because most known metallic deposits in the study area have not been dated by radioactive means, the above statement about ages of mineralization is an inference. Younger events, including Mesozoic plutonism and Tertiary faulting (see geologic time chart in Appendix), have only slightly modified the older geologic terrane.

The geologic history of the study area began in Early Proterozoic time with the accumulation of large amounts of siltstone and sandstone and minor amounts of basalt. Possibly syngenetic (same age as enclosing rocks), stratabound deposits in these rocks give part of the study area a low mineral resource potential for zinc, copper, silver, and gold. These rocks were highly metamorphosed, deformed, and intruded by at least three types of granitic rocks in Early Proterozoic time. Some of these granitic rocks contain pegmatite bodies that have a low resource potential for niobium, tantalum, uranium, rare-earth elements, and thorium.

During Middle Proterozoic time many mountain ranges in the area were intruded by granitic to syenitic stocks. The Clark Mountain Range to the west of the McCullough Range was intruded by mafic to silicic rocks and carbonatite bodies at this time. Although no rocks of Middle Proterozoic age are known to be present in the study area, aeromagnetic data suggest that rocks of this age may underlie the west side of the study area. If present, these rocks indicate that part of the area has a moderate potential for lanthanum and other rare-earth elements, uranium, thorium, and niobium.

The Proterozoic rocks remained relatively undisturbed until early Paleozoic time, when they were covered by a sequence of limestone, sandstone, and shale that ranges in age from about 550 to about 150 Ma (Cambrian to Jurassic). Those Paleozoic to Mesozoic units have since been eroded from the McCullough Range, but are present in ranges to the west and north. The absence of these rocks indicates that there is no resource potential for oil and gas and coal in the study area. Although common in nearby ranges, major episodes of Mesozoic deformation, pluton emplacement, and thrust faulting apparently did not affect the Proterozoic rocks in the McCullough Range. Breccia pipes and veins that may have formed during Laramide time give parts of the study area a moderate, low, or unknown mineral resource potential for silver, gold, lead, zinc, copper, or arsenic.

In Tertiary time, volcanic and volcaniclastic rocks covered the range. These rocks were faulted and eroded from much of the range. Veins that formed during deformation suggest that part of the study area has a moderate or low resource potential for gold, silver, lead, zinc, copper, or arsenic. Volcanic activity during late Tertiary time suggests that the area has a low energy resource potential for geothermal sources. Erosion since middle Tertiary time has created deposits of sand and silt that flank the range. These deposits and the Proterozoic crystalline rocks give the study area a low resource potential for sand and gravel and for dimension stone, respectively.

The South McCullough Mountains Wilderness Study Area contains no identified mineral resources and has no areas of high mineral resource potential. Five areas inside the study area boundary do have a moderate mineral resource potential either for silver, gold, lead, copper, and zinc in small vein deposits, for lanthanum and other rare-earth elements, uranium, thorium, and niobium in medium-size carbonatite bodies and dikes, for tungsten and copper in small to medium-size vein deposits, or for silver and gold in small vein or breccia-pipe deposits (fig. 2, pl. 1). These five areas make up about 6.2 mi^2 (square miles), or about 20 percent of the approximately 30.5-mi^2 study area. Six areas having an unknown resource potential either for gold, silver, lead, and copper in small vein deposits, for gold, silver, lead, zinc, copper, and arsenic in small vein or breccia-pipe deposits, for lanthanum and other rare-earth elements, uranium, thorium, and niobium in medium-size carbonatite bodies and dikes, or for tungsten and copper in small vein deposits make up about 7.2 mi^2, or about 24 percent of the study area. Four small areas have a low resource potential either for tin, for tungsten and copper, or for copper, gold, silver, and arsenic in small vein deposits. These four areas make up about 2.2 mi^2, or about 7 percent of the study area. The remaining 9 mi^2 (5.9 mi^2 covered by Tertiary volcanic rocks are omitted), or about 30 percent of the study area, has a low resource potential for zinc, copper, silver, and gold in medium to small stratabound deposits or for niobium, tantalum, uranium, rare-earth elements, and thorium in small pegmatite bodies; these areas also have an unknown mineral resource potential for gold and silver in small to medium-size breccia-pipe deposits.

The entire study area has no resource potential for oil and gas and coal as well as a low resource potential for these nonmetallic commmodities: dimension stone; sand and gravel; pegmatite minerals such as feldspar and mica; and for geothermal sources.

INTRODUCTION

As requested by the U.S. Bureau of Land Management (BLM), the U.S. Geological Survey and the U.S. Bureau of Mines studied 19,558 acres of the South McCullough Mountains Wilderness Study Area (NV–050–435). The boundaries of the study area are defined by the southern borders of sections 19, 20, 21, and 22 in T. 27 S., R. 61 E. on the south, the 5,600-ft contour and northeast-trending jeep trail and wash east of McClanahan Spring on the west, the hypothetical line connecting the 3,964-ft and 3,779-ft peaks in sections 34 and 35, respectively, in T. 25 S., R. 61 E. on the north, and the 5,200-, 4,000-, 3,600-, and 3,200-ft contours on the east (pl. 1). In this report the area studied is referred to as the "study area."

The study area, south of Las Vegas, Nev., and east of Mountain Pass, Calif., is in the McCullough Range, a north-trending range in southern Clark County (fig. 1). The area is accessible by trails leading away from a high-voltage transmission line connecting Boulder City, Nev., and Nevada Highway 68 on the east side of the range. Access on the northwest side is provided by trails leading away from a high-voltage transmission line between Boulder City, Nev., and Interstate Highway 15 near Mountain Pass, Calif. Vegetation is typical of the eastern Mojave Desert and consists of sparse growths of creosote on the alluvial fans and scrub oak, juniper, and ponderosa pine near the tops of the mountain ridges. Terrain within the study area is rugged, ranging from elevations of 3,200 ft to 7,026 ft.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and is the product of several separate studies by the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). Identified resources are classified according to the system of the U.S. Bureau of Mines and the U.S. Geological Survey (1980), which is shown in the appendix of this report. 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 energy sources (coal, oil, gas, oil shale, and geothermal sources). It is classified according to the system of Goudarzi (1984), which also is shown in the appendix. Potential for undiscovered resources is studied by the USGS.

Investigations by the U.S. Bureau of Mines

The USBM Western Field Operations Center, Spokane, Wash., did office work, fieldwork, and report writing during 1985 and 1986. Prior to the field work, claim and mining data were obtained from records of Lincoln and Clark Counties, from the BLM, and from claim owners. Federal publications, Nevada State publications, and USBM files were searched for production records; none was found. Claim owners were contacted for permission to examine properties and publish the results.

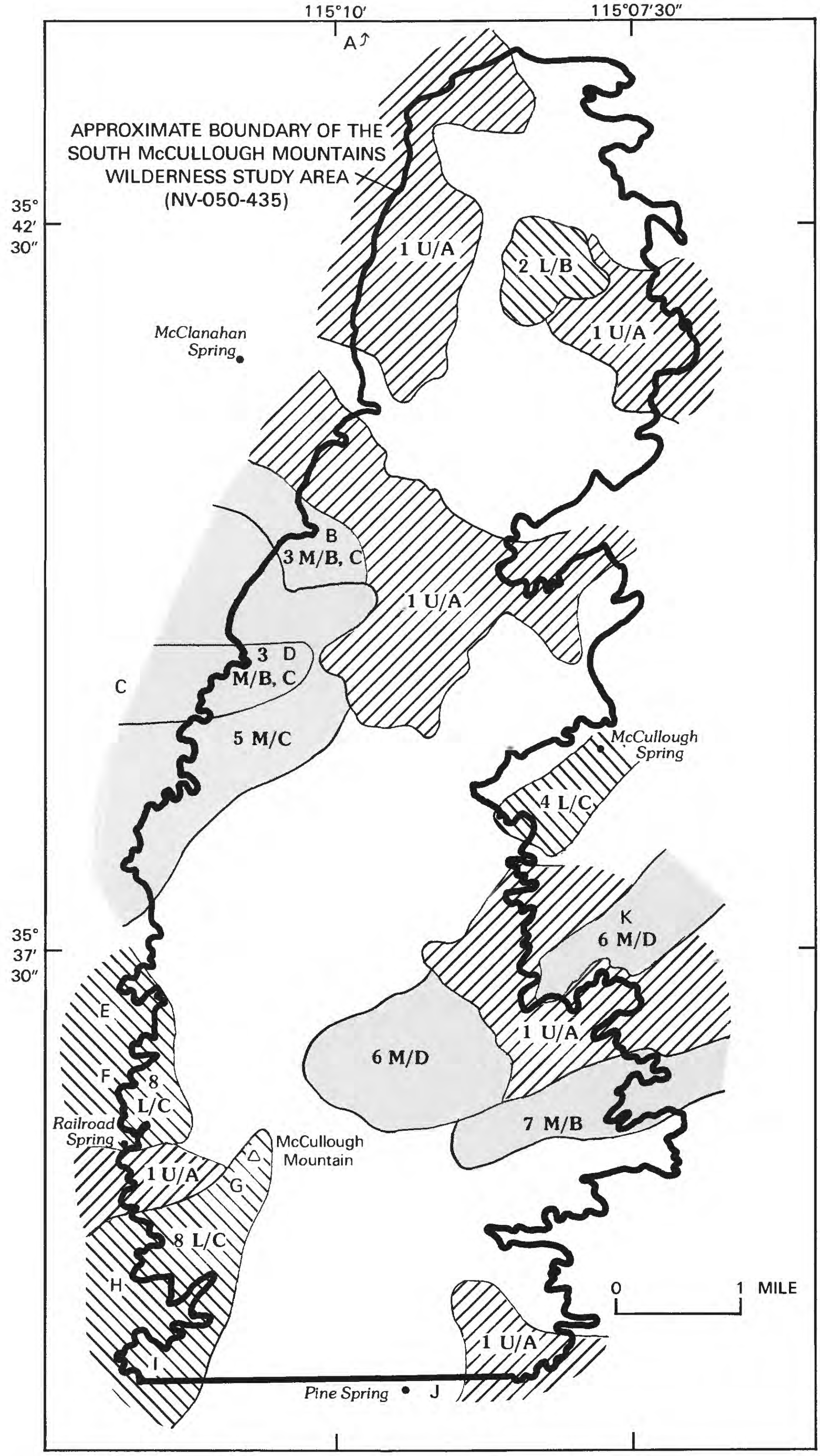


Figure 2 (above and facing page). Summary map showing mineral resource potential of the South McCullough Mountains Wilderness Study Area, Clark County, Nev.

EXPLANATION

[No geologic terrane having high mineral resource potential for any commodity was identified by this study. Except as designated below and except for that part covered by Tertiary volcanic rocks, entire area has low mineral resource potential, at certainty level C, for zinc, copper, silver, and gold in medium-size to small stratabound deposits. Same area also has low mineral resource potential, at certainty level C, for niobium, tantalum, uranium, rare-earth elements, thorium, and feldspar and mica in small pegmatite bodies. Same area also has unknown resource potential, at certainty level A, for gold and silver in small to medium-size breccia pipes. Entire study area has low mineral resource potential for sand and gravel, dimension stone, pegmatite minerals (feldspar and mica), and geothermal resources, at certainty level C. Entire study area has no mineral resource potential for oil and gas and coal, at certainty level D]

3 M/B, C
5 M/C
6 M/D
Geologic terrane having moderate resource potential for commodities listed in table below, at certainty levels B, C, or D—Number prefixes refer to areas listed in table below and in table 4

2 L/B
8 L/C
Geologic terrane having low resource potential for commodities listed in table below, at certainty level B or C—Number prefixes refer to areas listed in table below and in table 4

1 U/A
Geologic terrane having unknown resource potential, at certainty level A—Number prefixes refer to areas listed below and in table 4

J **Mineral sites within and adjacent to the study area**

Levels of certainty

A **Available data not adequate to estimate potential**

B **Data indicate geologic environment and suggest level of resource potential**

C **Data indicate geologic environment and give good indication of level of resource potential, but do not establish activity of resource-forming processes**

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

Summary of areas having metallic mineral resource potential in and adjacent to the South McCullough Mountains Wilderness Study Area, Clark County, Nev.

[Commodities listed in order of relative importance; commodities underlined are considered to be byproducts or trace metals that could be recovered if deposits containing principal metals were mined; where variable sizes of deposits are shown, the most probable size is listed first; size of deposits listed below; <, less than]

Map area (pl. 1 and fig. 2)	Resource potential	Level of potential/ level of certainty (see Appendix for explanation of symbols)	Commodities (listed in order of importance)	Size, type of deposit
All, except numbered areas below and part covered by Tertiary volcanic rocks	Low	L/C	Zn, Cu, Ag, Au	Medium to small, stratabound
	Low	L/C	Nb, Ta, U, REE, Th	Small, pegmatite bodies
	Unknown	U/A	Au, Ag	Small to medium, breccia pipe
1	Unknown	U/A	Au, Ag, Pb,, Cu	Small, vein
	Unknown	U/A	Au, Ag, Pb, Zn, Cu, As	Small, vein or breccia pipe
	Unknown	U/A	La, REE, U, Th, Nb	Medium, carbonatite bodies and dikes
	Unknown	U/A	W, Cu	Small, vein
2	Low	L/B	Sn	Small, vein
3	Moderate	M/C	Ag, Au, Pb, Cu, Zn	Small, vein
	Moderate	M/B	La, REE, U, Th, Nb	Medium, carbonatite bodies and dikes
4	Low	L/C	W, Cu	Small, vein
5	Moderate	M/C	La, REE, U, Th, Nb	Medium, carbonatite bodies and dikes
6	Moderate	M/D	W, Cu	Small to medium, vein
7	Moderate	M/B	Ag, Au	Small, vein or breccia pipe
8	Low	L/C	Cu, Au, Ag, As	Small, vein

Small vein deposit = <10,000 tons
Medium-size vein deposit = 10,000-250,000 tons
Small stratabound deposit = <5 million tons
Medium-size stratabound deposit = 5 million-50 million tons
Small pegmatite deposit = <30,000 tons
Small breccia pipe deposit = <5 million tons
Medium-size breccia pipe deposit = 5 million-20 million tons
Medium-size carbonatite deposit = 5 million-20 million tons

Field studies were conducted during April 1985. Forty-four rock samples were collected. The samples were initially prepared at the USBM Western Field Operations Center and sent to the USBM Reno Research Center, Nev., for analysis. Methods of analysis and detection limits are described in Close (1987). Detailed information is available from the Western Field Operations Center, E. 360 Third Ave., Spokane, WA 99202.

Investigations by the U.S. Geological Survey

The general geology of the McCullough Range was described on a reconnaissance basis by Hewett (1956), Longwell and others (1965), and Bingler and Bonham (1972). In all of these studies, the crystalline rocks within the study area were shown as undifferentiated Precambrian gneiss. Anderson (1971) examined the tectonic significance of volcanic rocks in the Eldorado Mountains, east of the McCullough Range, and proposed a stratigraphic nomenclature that is presently widely used for correlative volcanic rocks in this region. Volborth (1962, 1973) and Dexter and others (1983) described the Proterozoic igneous-metamorphic complexes exposed in the Gold Butte area and the Eldorado, Newberry, and northern Dead Mountains east and south of the McCullough Range. More recently, Clarke (1985) mapped in detail an area adjacent to the southern margin of the study area and presented thermobarometry and structural data relevant to the metamorphic and deformational history of crystalline rocks in that part of the range. Davis (1985) examined the structure exposed in over 4,500 ft of Miocene volcanic and volcaniclastic strata in the Highland Range, to the east of the McCullough Range.

The present geologic map (pl. 1) of the South McCullough Mountains Wilderness Study Area was prepared from field mapping by J.L. Anderson, E.D. Young, H.S. Clarke, S.E. Orrell, Michael Winn, C.S. Schmidt, E.I. Smith, and M.E. Weber in 1985. Sampling for a stream-sediment geochemical survey was done in 1985 by H.N. Barton, and the geochemical data were interpreted by Barton for this report. Geophysical data gathered during the National Uranium Resource Evaluation (NURE) program of the U.S. Department of Energy for the Kingman 1°×2° quadrangle (Western Geophysical Company of America, 1979) were analyzed by R.C. Jachens.

Acknowledgments.—The USBM thanks claimant L.C. Artman for the minerals data he provided. USBM geologists David Lipton and Vaughn Girol aided in the gathering of data for this report. The USGS thanks M.J. Blaskowski, who helped in preparation of the report.

APPRAISAL OF IDENTIFIED RESOURCES

By Terry J. Close
U.S. Bureau of Mines

Setting

USBM field studies involved a search for all known mineral sites; 11 were found and examined. Of the 11 sites, 4 are in the study area; the other 7 are within 1 mi of the boundary. The seven nearby sites were examined to determine if their mineralized zones extend into the study area; they apparently do not. No mineral resources were identified in the study area. A detailed description of the USBM work is contained in Close (1987).

Mining History

Lincoln and Clark County claim records show that the unorganized McCullough Mountain (McClanahan) mining district is located along the western edge of the study area. This district has no record of production. Gold, silver, and minor amounts of base metals (lead and copper) have been produced from Tertiary epithermal veins in the Eldorado district northeast of the study area. Silver, lead, and zinc have been produced from replacement, vein, and breccia-pipe deposits of Mesozoic to early Tertiary age in the Goodsprings district west of the study area. Gold, silver, and minor amounts of base metals (lead and copper) have been produced from Tertiary epithermal veins in the Searchlight district southeast of the study area (fig. 1). To the south are the Crescent Peak (turquoise, gold, silver, copper, and lead production) and the Sunset (gold, silver, copper, and lead production) mining districts. However, there is no indication that deposits in these districts extend into the study area.

The first mining claims in the study area (McCullough Mountain mining district) were recorded in 1911. Another 20 lode claims were located between the 1920's and the 1980's. Four claims staked in 1982 are currently (1986) valid. In addition, a large number of claims 1–2 mi south and east of the study area are currently held. There are no mineral leases or patented mining claims in the study area. The nearest patented mining claims are about 2 mi south of the study area in the Crescent Peak mining district.

Mines and Prospects

The metamorphic rocks along the west side of the study area are transected by a north-trending, west-dipping, normal fault zone. Most of the mineralized structures examined are associated with this fault zone and consist primarily of brecciated quartz veins. The veins examined are as thick as 15.0 ft, slightly stained with limonite and malachite, and (like many veins in Nevada) leached at the surface. Silver and gold are the principal elements of interest in the veins. Lead, zinc, copper, and arsenic are minor constituents. Tungsten is also noted in a scheelite-bearing vein in metamorphic rocks 0.5 mi east of the study area.

Approximate locations of the 11 sites examined during the study are shown by the letters A–K on figure 2 (see also pl. 1); pertinent data are summarized in table 1. Three of the 11 mineral sites may be significant. The surface material (Hacienda, Breyfogle, and Silver King prospects; fig. 2, letters B, D, and I, respectively) is leached and appears too low in grade and tonnage to be classified as identified resources. However, there are indications that metals may be more concentrated with depth: presence of persistent veins, rock alteration, sulfide boxwork, and malachite (a secondary copper mineral). Mineralized material is also apparent on waste dumps. However, arsenic, as indicated by sample assays, might complicate metallurgical treatment of mined material.

Large quantities of clay-rich alluvium and incompetent stone are in the study area. However, they are not economically suitable sources of construction material because there are higher quality competing sources of sand, gravel, and stone closer to current markets.

Recommendations for Further Work

Further investigation is needed at the three potentially significant mineral sites to determine if they have metal-bearing resources at depth. This work would include additional sampling, mapping, opening inaccessible workings, surface trenching, and drilling. If resources are identified at the sites, then the following should be done: (1) bulk sampling and metallurgical testing; and (2) feasibility studies, including mining and processing methods, costs, and market analyses. Bulk sampling and metallurgical testing would determine effects of the arsenic content on processing and reclamation technology. Cost and market analyses would determine value of the product and potential return on investment.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Ed DeWitt, J.L. Anderson, H.N. Barton, R.C. Jachens, M.H. Podwysocki, and D.W. Brickey
U.S. Geological Survey

Geology

Geologic Setting

The north-trending McCullough Range of southern Nevada is 35 mi long and forms the northern extension of the New York Mountains of California. The study area occupies the approximate center of the McCullough Mountain 15-minute quadrangle. The nearest population center is the town of Searchlight, Nev., approximately 12 mi east-southeast of the southern boundary of the study area (fig. 1).

The oldest rocks in the McCullough Range are granulite- to upper amphibolite-grade Early Proterozoic gneiss derived from metasedimentary and meta-igneous protoliths. Most meta-igneous bodies are about 1,700 Ma (J.L. Anderson and J.L. Wooden, unpub. data, 1986). Synkinematic to late kinematic Proterozoic plutons include augen gneiss and foliated to unfoliated granite. Notably, these rocks lack the calc-alkalic character of orogenic plutons typical of regions to the east (DeWitt, 1986 and in press). Younger, 1,400-Ma anorogenic plutons are present in many ranges of this region as part of a continent-wide province extending as far to the northeast as Labrador (Anderson, 1983 and in press). Late Proterozoic diabase dike swarms are locally prevalent (Davis and others, 1982; Hammond, 1983).

Missing from this range is the Paleozoic miogeoclinal section of strata with its structural assemblage of Mesozoic thrust faults. Because the section is present at Sheep Mountain, only 5 mi west of the McCullough Range, farther west in the Spring Mountains, Clark Mountain Range, and south in the New York Mountains, it is reasonable to suppose that these strata once covered the McCullough Range. Evidently the Paleozoic strata were eroded during Late Cretaceous or early Tertiary time, prior to deposition of Tertiary volcanic rocks.

A tilted section of Miocene volcanic rocks covers the crystalline rocks of the McCullough Range on the northeast and is exposed primarily along parts of the periphery of the range. Small Tertiary (Miocene?) granitic intrusive rocks are present to the east at Searchlight, and altered and mineralized material containing gold and silver to the south at Crescent Peak may indicate Tertiary intrusive rocks at depth in that area.

Table 1. Summary descriptions of mineral sites within and adjacent to the South McCullough Mountains Wilderness Study Area, Clark County, Nev.

[Study area sites underlined may have inferred resources at depth but lack specific resource data; asterisk (*) signifies a location outside the study area; principal commodities are shown in parentheses: As (arsenic), Cu (copper), Au (gold), Pb (lead), Ag (silver), W (tungsten), and Zn (zinc)]

Letter on map (fig. 2, pl. 1)	Name	Description	Workings and production	Sample and resource data[1]
A	McCullough Pass prospect*	A pegmatite dike exposed for 140 ft in biotite gneiss averages 13.6 ft thick. The dike strikes N. 50° W., dips 65° NE., is kaolinized, and composed of limonitic quartz and microcline.	One 140-ft trench--------	Two chip samples across the dike had no apparent mineral concentrations
B	Hacienda prospect (Ag, Au)	A vein averaging 5.9 ft thick was traced for 670 ft in limonitic, silicified, biotite gneiss intruded by quartz monzonite and pegmatite dikes. The vein strikes N. 70° to 80° W., dips 85° to 90° SW., is leached, and is mainly quartz and sparse limonite and malachite. Boxwork on the dumps indicates sulfides may be at depth.	One inaccessible adit that may be 80 ft long, three bulldozer trenches that total about 90 ft, and four small pits and cuts.	USBM personnel took 16 chip samples. The claimant supplied the data for 11 samples he had taken. The USBM samples contained as much as 10 ppm copper, 210 ppm arsenic, 13 ppm lead, and 70 ppm zinc. Seven of eleven samples taken by the claimant contained as much as 0.0006 oz/ton gold and 0.006 oz/ton silver. The remaining four samples, from a working on the south side of the vein, had 0.015 to 0.304 oz/ton gold and 0.09 to 18.09 oz/ton silver. USBM samples were from leached outcrops and do not indicate mineral resources. However, the malachite and sample data supplied by the claimant suggest that silver, gold, and copper resources may be present below the leached zone.
C	Dry Springs prospect* (As)	A poorly exposed, 4.0-ft-thick quartz vein in biotite gneiss strikes N. 25° W. and dips 55° NE. The vein is brecciated and contains fault gouge.	An area that measures 150 by 60 ft has been bulldozed.	A chip sample across the vein had 7.9 ppm copper, 190 ppm arsenic, and 34 ppm zinc.
D	Breyfogle prospect (Ag, Pb, Zn, As)	Two poorly exposed veins are in biotite gneiss intruded by quartz monzonite. The principal vein averages 1.5 ft thick, dips 80° SE., and was traced for 50 ft along a strike of N. 60°-70° E. The second vein, exposed only in a pit, is 2 ft thick, strikes N. 50° E., and dips 90°. Both veins are leached, and mainly quartz with calcite, limonite, specularite, arsenopyrite, and galena. The gneiss surrounding the veins is limonitic and silicified.	A flooded shaft estimated to be about 100 ft deep and three small prospect pits.	Six samples were taken. The main vein was estimated to average 0.26 oz/ton silver, 0.07 percent lead, and 0.049 percent zinc, on the basis of two chip samples. A chip sample across the second vein contained 1.9 oz/ton silver, 0.19 percent lead, and 0.18 percent zinc. Samples also contained 0.011-0.02 percent arsenic. Two grab samples of dump material had no significant mineral concentrations. The vein exposures are too small and low-grade to be classified resources. However, the chip samples were of leached surficial material. A grab sample of quartz from a stockpile at the shaft contained 3.1 oz/ton silver, 1.0 percent lead, and 0.7 percent zinc, indicating higher grade material may be at depth, below the leached zone. An examination of the vein exposure in the flooded shaft would give a better indication of possible resources.
E	Prospect No. 5* (As)	A 1.5-ft-thick vein is exposed for 5 ft in biotite gneiss. The vein strikes N. 20° E., dips 80° SE., and is composed of quartz with limonite and pyrite.	A shaft 6 ft deep.	A chip sample across the vein contained 11 ppm copper, 12 ppm lead, 120 ppm arsenic, and 40 ppm zinc.

F	Prospect No. 6* (Cu, As)	Adjoining the study area boundary is a vein that strikes N. 35° W., dips 85° SW., and is mainly quartz with malachite and arsenopyrite. The vein exposure is 2 ft thick, 10 ft long, and in limonitic, silicified, biotite gneiss intruded by quartz monzonite. There is no indication that the vein extends into the study area.	Small prospect pit.	Two samples were taken. A chip sample across the vein had 90 ppm copper, 160 ppm arsenic, and 40 ppm zinc. A grab sample of quartz from the dump contained 1.2 percent copper, 140 ppm cobalt, 190 ppm arsenic, and 59 ppm zinc. The significantly higher copper concentrations in the grab sample suggest that copper-bearing material may be at depth.
G	Prospect No. 7	A vein exposure 4.3 ft thick and 10 ft long strikes N. 55° W., and dips 65° NE. in limonitic, silicified, biotite gneiss that has been intruded by quartz monzonite. The vein is mainly limonitic quartz breccia.	One small pit.	A chip sample across the vein contained no significant mineral concentrations.
H	Prospect No. 8* (As)	A poorly exposed, 5.8-ft-thick, limonitic quartz vein strikes N. 44° E., and dips 53° NW., in biotite gneiss.	One adit 8 ft long.	A chip sample across the vein contained 200 ppm arsenic and 34 ppm zinc.
I	Silver King prospect (Au, Cu, As)	One principal and two smaller veins are exposed in an area that measures 1,000 by 2,000 ft. The veins are 0.3-7.0 ft thick, trend N. 44° E. to S. 42° E., dip steeply, and are in silicified, limonitic, biotite gneiss. The principal vein averages 2.7 ft thick and can be traced for 1,000 ft. Its surface exposures are leached and brecciated, and composed of quartz, calcite, and sparse limonite and malachite. Boxwork on the dumps suggest that sulfides are a few feet below the surface.	A 15-ft adit and four prospect pits. The workings indicate a few tons of ore production; however, none was recorded.	Seven samples were taken; five chip samples across the principal vein and two across smaller veins. The samples contained as much as 1,800 ppm copper, 190 ppm arsenic, 390 ppm lead, and 310 ppm zinc. One sample had 0.01 oz/ton gold. All the samples were from leached outcrops. The vein exposures are too low in grade to be classified resources. However, a sample containing copper (from the principal vein) and a sample containing gold (from a smaller vein), as well as the malachite and boxwork, indicate that resources may occur at depth.
J	Apprentice prospect*	A 3-ft-thick pegmatite dike strikes north and dips 55° W. in limonitic biotite gneiss. The dike is mostly quartz with microcline.	A 20-ft adit.	A chip sample across the dike contained no significant metal concentrations.
K	War Lord prospect* (W)	East of the study area is a 4.6-ft-thick, 78-ft-long vein exposure that strikes N. 34° E., and dips 80° SE. in limonitic, silicified schist that contains calcite, hornblende, biotite, and garnet. The vein is composed of small lenses of fine-grained quartz that contain malachite and scheelite. The zone trends towards the study area but probably does not extend into it.	Two small prospect pits and a chute to carry ore down to a small, partly dismantled, semiautogenous mill.	Six samples were taken. Two chip samples across the vein contained a trace of gold, 280 ppm copper, 790 ppm tungsten, and 120 ppm zinc. A grab sample of quartz from the ore chute contained 1,300 ppm tungsten. Three grab samples of quartz from the workings and the mill contained as much as 0.02 oz/ton silver, 26 ppm copper, 880 ppm tungsten, and 190 ppm zinc.

[1]Precious metals are reported in troy ounces.

Phanerozoic magmatic and metamorphic events that could have affected the McCullough Range include (1) Jurassic to Cretaceous emplacement of plutons and (2) Tertiary mylonitization related to development of mylonitic detachment terranes (so-called metamorphic core complexes). Phanerozoic plutons are not recognized in the study area, and mylonitic shear zones that are present do not have the regionally penetrative fabric characteristic of those developed in mylonitic detachment terranes (Rehrig and Reynolds, 1980; Davis and others, 1982, 1983; Reynolds and others, 1986). Compared to many of the mountain ranges in this region, the McCullough Mountains have had a less complicated history since Early Proterozoic time. Notably, 1,400-Ma plutons and Late Proterozoic diabase dikes are absent. Although the study area contains a considerable amount of granitic material, we infer that most, if not all, of the granite is Early Proterozoic. This inference is based on the similarity of their deformational fabrics to those in the older granulite-facies gneiss. Thus, the McCullough Range crystalline complex is an example of Early Proterozoic crust that has not been profoundly affected by Mesozoic and Tertiary thermal and deformational events.

Early Proterozoic Preplutonic Rocks

High-grade metamorphic rocks (unit Xgn, pl. 1) derived predominantly from sedimentary protoliths make up about 50 percent of the bedrock of the study area. The metamorphic rocks include gneiss, migmatite, and minor amounts of amphibolite and are similar to granulite- or upper amphibolite-facies gneiss elsewhere in the eastern Mojave Desert (DeWitt and others, 1984; Anderson and others, 1985; Miller and others, 1986). Typically, the gneiss forms dark outcrops that characterize a gently sloping topography.

The most abundant rock type in this unit is fine- to coarse-grained, migmatitic to nonmigmatitic quartz-plagioclase-alkali feldspar-biotite-hercynite ± garnet ± sillimanite ± cordierite gneiss containing gray alkali feldspar porphyroblasts. Parallel alignment of biotite (and sillimanite and cordierite where present) defines a prominent foliation. Small-scale isoclinal folds and refolded folds are common. Locally, the gneiss contains abundant igneous material and can be described as a migmatite. Amphibolite and metamorphosed ultramafic rocks, both foliated and granoblastic, are isolated layers and pods within the gneiss. Major minerals in the amphibolite include hornblende, clinopyroxene, plagioclase, quartz, biotite, and minor cummingtonite. Orthopyroxene is present, but less common. The meta-ultramafic rocks consist of actinolitic hornblende, hypersthene, and biotite and are present as small layers (less than 10 ft thick) associated with amphibolite. Similar Proterozoic ultramafic bodies are noted in the Gold Butte area of southern Nevada (Volborth, 1962; Dexter and others, 1983). Many amphibolite bodies and all of the meta-ultramafic bodies are too small to be shown separately on plate 1.

Coarse-grained to pegmatitic, migmatitic leucogranite and granitic gneiss (unit Xgg, pl. 1) intrude the older gneiss. The largest bodies of leucogranite are east of McCullough Mountain. Granitic gneiss is most common in the northern part of the study area. Together, the two rock types make up less than 5 percent of the bedrock. Biotite and garnet are the dominant mafic minerals in the leucogranite. Although the leucogranite is mineralogically similar to pegmatite related to younger granite, it is distinctly older, as documented by its deformed nature. Modally, the granitic gneiss is a syenogranite to granodiorite (IUGS classification, Streckeisen, 1973) that contains 5–22 modal percent biotite as the chief mafic phase. Deformed feldspar phenocrysts are characteristic. Garnet, in trace amounts, is spatially associated with sparse, irregularly distributed biotite clusters. Hornblende (as much as 2 modal percent) is partly replaced by biotite. Accessory phases include zircon, apatite, and magnetite.

The mineralogy of the gneiss, amphibolite, and metamorphosed ultramafic rocks indicates low-pressure granulite-facies metamorphism (Fyfe and others, 1958; Green and Ringwood, 1967; Absher and McSween, 1985). The absence of muscovite in the gneiss and the presence of the assemblage cordierite-almandine garnet-biotite in some of the gneiss suggest the low-pressure facies of granulite metamorphism (deWaard, 1966; Green and Ringwood, 1967; Turner, 1968). The presence of cummingtonite instead of garnet in amphibolite is also consistent with low-pressure granulite-facies conditions (Miyashiro, 1973).

Preliminary thermobarometry of the gneiss indicates latest equilibration at 615±15 °C and 1.3±0.2 kb. The presence of hercynite implies that peak metamorphism was probably 50–100 °C higher. Similar granulite-facies gneiss in the Gold Butte region yields estimates of 750 °C at 3.1 kb (Warren Thomas, oral commun., 1985). Gneiss exposed in many ranges farther south, such as the Eldorado, Newberry, Dead, Bill Williams, and Whipple Mountains, also contains high amphibolite- to granulite-facies mineral assemblages. Hence, the metamorphism recorded in the oldest rocks of the McCullough Range indicates a widespread, very high grade event inferred to have taken place during Early Proterozoic time.

Early Proterozoic Plutonic Rocks

Foliated and nonfoliated granitic and dioritic plutons intrude the granulite-facies gneiss throughout the study area (pl. 1). Outcrops of these plutonic rocks are abundant in the central parts of the area and are responsible for the steep, rugged topography. These intrusive rocks clearly post-date the complex deformation of the gneiss and apparently were not subjected to granulite-facies conditions. However, they commonly exhibit a foliation parallel to that in the older metamorphic rocks. The absence of obvious retrograde contact aureoles suggests that the plutons were emplaced prior to significant cooling of the country rock. Hence, the plutons were probably emplaced late in the deformational history of the gneiss and slightly after the peak of prograde metamorphism.

Dark-gray, fine-grained hornblende-biotite quartz diorite to diorite forms a pluton northwest of McCullough Mountain (unit Xd, pl. 1). The quartz diorite and diorite pluton cuts Early Proterozoic granulite-facies gneiss (unit Xgn) and in turn is cut by numerous small dikes of granite (units Xg and Xgr). Augite, partly or completely replaced by hornblende, is present in more mafic varieties. Mafic minerals make up as much as 50 modal percent of the rock. Accessory phases include apatite, zircon, opaque minerals, and secondary epidote. Unlike most granitic rocks, this mafic body is generally unfoliated, indicating that its hornblende-rich composition resisted development of foliation.

The oldest granitic rocks are bodies of porphyritic granite (unit Xg, pl. 1) that correspond to the porphyritic monzogranite of Pine Spring, porphyritic monzogranite of McClanahan Spring, and inclusion-rich porphyritic monzogranite of Railroad Spring (Anderson and others, 1985). Light-gray, mildly foliated, medium- to coarse-grained porphyritic biotite granite (unit Xg) crops out in the northern and western part of the study area, from near Railroad Spring to east of McClanahan Spring (pl. 1). Small outcrops of the granite are present just south of the study area (Clarke, 1985; pl. 1). Bodies of porphyritic granite cut the granulite-facies gneiss (unit Xgn) and are intruded by granite and pegmatite (unit Xgr). Parallel alignment of biotite and quartz aggregates defines a weakly developed foliation in the granite. Perthitic microcline phenocrysts, 0.5–4 in. in length, are characteristic of the granite. The chief mafic mineral, biotite, ranges from 5 to 30 modal percent. Minor amounts of white mica intergrown with biotite and plagioclase (An_{33-34}) are probably secondary in origin as shown by comparison of its composition to proven igneous muscovite (Anderson and Rowley, 1981; Miller and others, 1981; Monier and others, 1984). Primary igneous garnet (Miller and Stoddard, 1980), which is present as irregularly distributed clusters associated with interstitial biotite, comprises less than 2 modal percent of the granite. Accessory phases include well-developed apatite and zircon. Between Railroad Spring and McClanahan Spring, the bodies of granite contain numerous xenoliths of granulite-facies gneiss (unit Xgn). Xenoliths consist of garnet-biotite paragneiss, pegmatite, and large xenocrysts of quartz and alkali feldspar evidently derived from pegmatite.

The largest pluton and body of granite (unit Xgr) in the study area is centered on McCullough Mountain but extends north-south the length of the area (pl. 1). The pluton is equivalent to the biotite monzogranite of Anderson and others (1985) and is a tan, medium-grained biotite granite. Distinctive mafic clots composed primarily of biotite and garnet and rimmed by felsic halos are common in many parts of the granite, particularly near the granulite-facies gneiss. The clots are highly variable in size, but are normally less than 7 in. long; clots are either round or ellipsoidal. The felsic halos and concentration of clots near contacts with the gneiss suggest that the clots are xenoliths; the felsic halos represent a reaction rim next to the granitic magma.

The granite contains abundant microphenocrysts of perthitic microcline. Biotite is the principal mafic mineral, constituting 3–17 volume percent of the rock. Accessory sericite is intergrown with both biotite and plagioclase (An_{18-29}), but, as also noted for the porphyritic granite (unit Xg, pl. 1), the mica is probably secondary in origin. Sparse, irregularly distributed garnet, which is associated with biotite, constitutes 1–4 volume percent of the granite. The almandine-rich and spessartine-poor composition of the garnet suggests that they may be xenocrysts. Accessory minerals include magnetite, apatite, and zircon.

Dikes of this granite intrude every pre-Tertiary rock in the study area except bodies of pegmatite (also included as part of unit Xgr). Granite dikes, presumably derived from the granite pluton, intrude the hornblende quartz diorite, contain hornblende, and have less modal quartz than all other bodies of granite. This mineralogic difference may result from contamination of the granite dikes with material from the quartz diorite.

Pegmatite and minor aplite dikes and pods cut the granite (unit Xgr) and all pre-Tertiary rocks; these are mapped as part of unit Xgr. These bodies pervasively intrude much of the granite in a lit-par-lit fashion to such a degree that locally only 10 percent of the granite remains.

Proterozoic Structural Features

Three deformational events are recorded by structures in Early Proterozoic rocks in the study area. These events, from oldest to youngest, are (1) formation of foliation during high-grade metamorphism; (2) minor open to tight or isoclinal folding of the metamorphic foliation; and (3) development of mylonitic shear zones. The metamorphic foliation in Early Proterozoic gneiss in the study area generally strikes north-northeast and dips to the west at moderate to steep angles (pl. 1). This metamorphic foliation has been deformed into open to tight, small-scale (less than 3-ft amplitude) folds. Fold axes plunge westward at moderate to steep angles (unit Xgn, pl. 1). Foliation in the granitic gneiss (part of unit Xgg) is parallel to that in the granulite-facies gneiss (unit Xgn, pl. 1). This parallelism suggests that deformation of the granitic protolith may have been related to the metamorphic foliation-forming event.

The porphyritic granite (unit Xg) and granite (unit Xgr) contain a foliation that is parallel to the foliation in the older gneiss (pl. 1). Contacts between the granitic rocks and the country rock generally intersect the metamorphic foliation at high angles, indicating that the plutons were emplaced discordantly. In some of the granitic bodies, the foliation is defined not only by mineral alignment but also by compositional layering; this suggests that at least some of the foliation is of primary igneous origin. However, textural evidence for cataclastic deformation of most granitic rocks is abundant, and it is clear that much of their foliation was at least in part tectonically created.

Mylonitic shear zones ranging from less than 1 in. to as much as 75 ft thick cut Early Proterozoic gneiss (unit Xgn) and all younger plutonic rocks (units Xgg, Xg, and Xgr). The shear zones strike north-northeast and dip to the west at low to moderate angles. Mylonitic foliation within the shear zones is, in general, subparallel to the metamorphic foliation. Lineations in the mylonitic shear zones plunge 5°-65° to the west-southwest. Both the plunge of lineation and the dip of foliation within the shear zones appear to increase to the north. Granitic plutons, particularly granite (unit Xgr) are cut by the greatest number of mylonitic shear zones. Mylonitic shear zones in granite are often enriched in secondary sericite and are characterized by monominerallic bands of quartz and biotite that wrap around large feldspar porphyroclasts. Garnet is concentrated in the biotite bands. Shear zones generally do not cross cut, but rather bifurcate and surround amphibolite xenoliths in younger granite bodies. Evidently, amphibolite inclusions acted as resistant boudins during deformation. Mylonitization is believed to be Proterozoic, on the basis of K-Ar dates that are as old as Late Proterozoic (J.L. Anderson, unpub. data, 1986).

Tertiary Rocks

Tertiary strata in the study area are composed almost exclusively of volcanic and volcaniclastic rocks. Minor dikes of diabase, andesite, and rhyolite cut the Early Proterozoic crystalline complex but are not shown on plate 1. The volcanic section is exposed in the northeastern part of the study area, from McCullough Spring to the northern boundary (pl. 1). Tertiary rocks form steep cliffs and a rugged, deeply incised topography.

Because of overall similarities in stratigraphy to Miocene volcanic strata in the Eldorado Mountains to the east, these Tertiary volcanic rocks in the McCullough Range are considered to be temporally and stratigraphically correlative. In the Eldorado Mountains, Anderson (1971) subdivided the volcanic section into (1) the Patsy Mine Volcanics (K-Ar dates of 15–17 Ma); (2) the tuff of Bridge Spring (K-Ar date of 14.7 Ma); and (3) the Mount Davis Volcanics (K-Ar dates of 12–14 Ma). We consider the tuff of Bridge Spring to be part of a regionally continuous unit but believe that both older and younger volcanic strata in the McCullough Range were derived from different sources than were rocks of equivalent age in the Eldorado Mountains.

The volcanic rocks were deposited on a surface of considerable topographic relief that rose sharply to the west. Hence, basal volcanic units thin and pinch out westward, and lowermost strata are progressively younger to the west. No source areas for the volcanic units have been identified in the study area. Thin flows interbedded with thick volcaniclastic units and the scarcity of feeder dikes suggest that the volcanic section in the area represents the distal facies of a stratovolcano.

A discontinuous, waterlaid conglomerate, stratigraphically between Early Proterozoic basement and Tertiary volcanic rocks, crops out in several places in the study area, but is not shown on plate 1. Clasts consist of Proterozoic crystalline rocks, Late Proterozoic Stirling Quartzite, Late Proterozoic and Lower Cambrian Wood Canyon Formation, and Paleozoic carbonate rocks. The conglomerate is regional in extent, being present in the unnamed range west of the McCullough Range, in the River Mountains, and in the Eldorado Mountains. In the McCullough Range the conglomerate is as much as 100 ft thick. The age of the conglomerate is speculative, but it is probably equivalent to channel-fill deposits described by Young and McKee (1978) to the northeast on the margin of the Colorado Plateau and by Smith (1982) and Choukroune and Smith (1985) on Saddle Island in Lake Mead. These units are interpreted to be Late Cretaceous to early Tertiary in age.

The oldest Tertiary volcanic rocks are represented by the Patsy Mine Volcanics (unit Tp, pl. 1), which can be divided into three units. The lower part of the section is composed primarily of porphyritic basalt containing phenocrysts of olivine pseudomorphs, clinopyroxene, and plagioclase. A 19-ft-thick pyroclastic unit, rich in phenocrysts of sanidine, biotite, clinopyroxene, plagioclase, and magnetite, and lithic fragments of pumice, is commonly present at the base of the section. This lower part of the section is 130–480 ft thick in the study area.

A sequence of interbedded porphyritic basalt and porphyritic andesite flows and waterlaid volcaniclastic sandstone and conglomerate, called the "middle section," overlies the lower part of the Patsy Mine Volcanics. The andesite contains large clinopyroxene and oxyhornblende phenocrysts set in a matrix of glass, plagioclase, and minor clinopyroxene. The conglomerate and other poorly sorted and bedded clastic rocks contain clasts of porphyritic basalt, porphyritic andesite, and dacite.

This middle section is approximately 65 ft thick near McCullough Spring, but thins to less than 10 ft about 1 mi to the north. The section is thin over much of the northern part of the study area, but thickens to more than 480 ft near McCullough Pass. This thickness variation presumably reflects the paleotopographic surface developed on basalt of the lower part of the Patsy Mine Volcanics. Hornblende andesite in the middle section thickens from the McCullough Spring area southeastward and may have been derived from a source area in the Highland Spring Range.

The upper part of the Patsy Mine Volcanics near McCullough Pass is composed mostly of porphyritic andesite. Some flows have glassy bases and grade upward into vitrophyric andesite. Phenocrysts include oxyhornblende and augite. The matrix is composed chiefly of plagioclase (An_{40}) and minor biotite. North of McCullough Spring (pl. 1), porphyritic andesite is interbedded with flows of porphyritic pyroxene andesite and porphyritic basalt. The basalt is composed of clinopyroxene, plagioclase, and olivine pseudomorphs. The upper part of the section is more than 250 ft thick near McCullough Spring, but it is absent at the northern boundary of the study area. The major source areas for much of both the Patsy Mine and Mount Davis Volcanics probably lie to the north near Black Mountain, in the northern McCullough Range (E.I. Smith, unpub. data, 1985).

The tuff of Bridge Spring (lower part of unit Tu, pl. 1) in the study area is composed of several pyroclastic flow units. The basal unit is a welded tuff approximately 1–30 ft thick that contains plagioclase, sanidine, biotite, and augite phenocrysts and lithic fragments of hornblende andesite and basalt. Just north of the study area this welded basal unit is interbedded with a 6-ft-thick clastic unit consisting of waterlaid debris flows, air fall material, and minor welded tuff. Lithic clasts consist of Proterozoic gneiss and granitoids. The upper part of the tuff is a lithic-rich, poorly welded pyroclastic flow that varies in thickness from more than 48 ft to less than 1 ft. This upper tuff is absent in exposures west of the unnamed wash that is the western boundary of the study area (pl. 1), but is a prominent marker in exposures east of the wash, where it is approximately 30 ft thick. The tuff of Bridge Spring pinches out approximately 3 mi north of the northern boundary of the study area. Southwest to northeast flow is documented by megascopic measurements of flow direction in both the McCullough Range and the Eldorado Mountains (E.I. Smith, unpub. data, 1985). Thus, the source of the tuff lies to the southwest, in the eastern Mojave Desert of California.

Overlying the Patsy Mine Volcanics and tuff of Bridge Creek are the Mount Davis Volcanics (also part of unit Tu), which are composed of basalt and locally interbedded dacite. Basalt flows (10–20 ft thick) commonly have scoriaceous bases, massive interiors, and vesicular tops. The basalt contains augite, olivine pseudomorphs, and plagioclase phenocrysts. The Mount Davis Volcanics are less than 60 ft thick in the study area.

Surficial units (unit Qu, pl. 1) composed of silt, sand, and coarser grained grus occupy the major washes in the study area.

Tertiary Structural Features

The major Tertiary structures in the study area are north-trending normal faults that dip steeply westward, most in excess of 70°. Fault displacements within the Early Proterozoic rocks are difficult to measure, but are generally less than about 50 ft. Tertiary volcanic units are tilted approximately 20°–45° to the east; normal faults therefore intersect bedding approximately at right angles. Average displacements along individual faults range from less than 60 ft in the northernmost part of the Tertiary volcanic rocks to as much as 290 ft in the southern part. The largest fault displacement is along the north-northeast-striking, west-dipping normal fault exposed just east of the wash near the northwest boundary of the study area (in sec. 9, T. 26 S., R. 61 E., pl. 1). This fault juxtaposes basalt of the Mount Davis Volcanics (part of unit Tu) and Early Proterozoic basement and has an offset in excess of 1,920 ft.

Northeast-striking, east-dipping normal faults in the study area may be antithetic to the more abundant west-dipping faults. Relatively small normal faults that strike east-northeast or east-southeast cut the more northerly striking faults and represent the youngest structures in the area. Displacements along the north-striking normal faults are not large enough to cause the eastward tilting of 20°–45° observed in the Tertiary volcanic rocks. Tilting could be explained by yet-unrecognized west-dipping frontal normal faults on the east flank of the McCullough Range. Such north-striking frontal normal faults are characteristic of other mountain ranges in the region (Volborth, 1973).

Geochemistry

Heavy-mineral concentrates from stream sediments and samples from rocks were selected as appropriate sample media for the reconnaissance geochemical survey conducted during April of 1985. Details on sample preparation and analysis, along with the presentation of data and sample sites, are found in Barton and Day (1988). Heavy-mineral concentrates and

Table 2. Slightly anomalous concentrations of selected elements in heavy-mineral concentrates from minus-100-mesh fraction of stream-sediment samples from the South McCullough Mountains Wilderness Study Area, Clark County, Nev.

[All concentrates heavier than bromoform (specific gravity 2.86) and nonparamagnetic at 1.0 amp on a Frantz magnetic separator; concentrations in parts per million except Ca, which is in percent; ---, element not found in anomalous concentration; >, greater than; <, less than; number in parentheses indicates those concentrations assumed to be slightly anomalous in each sample type; all elements in concentrates analyzed by six-step spectrographic method by Gordon Day]

Sample No.	Au (20.0)	Ag (1.0)	W (200)	Sc (50)	Ba (5,000)	Ca (30%)	Th (200)	La (700)	As (500)	Mo (20)	Pb (100)	Sn (20)	Y (1,000)
MA001	---	---	---	---	---	50	---	---	---	---	---	---	2,000
MA004	---	---	700	---	---	---	---	---	---	20	---	---	---
MA009	---	---	---	---	7,000	---	---	---	---	---	---	---	1,500
MA010	---	---	---	50	---	---	---	---	---	---	---	---	---
MA011	---	---	---	---	---	---	---	700	---	---	---	20	---
MH006	---	---	---	---	---	---	---	---	---	---	---	20	---
MH011	---	---	---	50	---	---	---	---	---	---	---	---	---
MH013	---	---	200	---	---	---	---	---	---	---	---	---	---
MH016	---	---	---	---	---	---	300	---	---	---	---	---	---
MH018	---	---	500	---	---	---	---	---	---	---	---	---	---
MH019	---	5	---	---	---	---	---	---	---	---	---	---	---
MH022	---	---	---	---	---	---	---	---	---	---	100	---	---
MH024	---	---	---	---	---	---	---	---	---	---	---	---	1,000
MH025	---	---	---	---	---	---	---	---	---	---	---	---	2,000
MG002	---	---	---	---	---	---	---	---	---	---	500	---	---
MG004	---	---	---	---	>10,000	---	---	---	---	---	---	---	---
MG011	---	---	---	---	---	50	---	---	---	---	---	---	---

rock samples were analyzed for 31 elements by the semiquantitative emission spectrographic method of Grimes and Marranzino (1968). Heavy-mineral-concentrate samples were collected from 52 stream-bed sites either within the study area or outside but having drainage basins within the study area, resulting in a sampling density of approximately 1.24 samples/mi^2.

Samples of heavy-mineral concentrates provide information about the chemistry of a limited number of minerals in rock material eroded from the drainage basin upstream from each sample site. The selective concentration of minerals permits the determination of some elements that are not easily detected in stream-sediment samples. Two rock samples were collected from outcrops to provide information on element concentrations in rocks that have not been affected by mineralization or alteration.

Only a few weakly anomalous concentrations of elements were found in the heavy-mineral concentrates (table 2). These were defined to be anomalous by inspection of the data without statistical analysis because of the low number of samples (52) and the fact that many samples did not contain detectable amounts of certain elements.

The following are some of the anomalous values, arranged by element, that were determined for heavy-mineral concentrates:

Tungsten.—Three sites had concentrations of 200 parts per million (ppm) or higher. Site MH013 at McCullough Spring (pl. 1) had 200 ppm, and sites MA004 and MH018, both approximately 2 mi east-northeast of McCullough Mountain, had 700 and 500 ppm, respectively.

Silver.—One site, MH019, 3 mi east of McCullough Mountain (pl. 1) had 5 ppm silver.

Lead.—One site, MG002, 2 mi northeast of McCullough Spring (pl. 1) had 500 ppm. This was the only lead concentration greater than 100 ppm.

Barium.—One site, MG004, 2 mi northeast of McCullough Mountain (pl. 1) and near two of the above sites containing tungsten, had greater than 10,000 ppm barium. Another site, MA009, on the west side of the range, contained 7,000 ppm barium.

All of the above-mentioned anomalous values are for sites extending along the eastern side of the range from a point about 2 mi east of McCullough Mountain to a point approximately 5 mi to the north.

The anomalous concentrations of silver, lead, and barium may be indications of mineralization of the type described by Longwell and others (1965) for the Crescent district 3 mi to the south. These are described as quartz lenses in a shear zone in Precambrian granite gneiss. The quartz contains a small amount of gold, silver, copper, and lead, and accessory gangue barite.

The anomalous tungsten values may indicate mineralization of the low-level type described by Longwell and others (1965) in the Gold Butte and Copper King districts, approximately 70 mi east of Las Vegas, in which scheelite is present in joints and fractures near granitic or hornblendite dikes cutting Precambrian schist.

Geophysics

Aeromagnetic Survey

Aeromagnetic data over the South McCullough Mountains Wilderness Study Area were obtained from a survey of southern Nevada (U.S. Geological Survey, 1979). Total-field magnetic data were collected along east-west flight lines spaced about 1 mi apart and at a nominal height of 1,000 ft above terrain. Because of the rugged topography in the study area, actual terrain clearance varied from about 300 ft to 1,600 ft. Corrections were applied to the data to compensate for diurnal variations of the Earth's magnetic field, and the International Geomagnetic Reference Field (updated to the month of the survey) was subtracted to yield a residual magnetic map.

Comparison of the aeromagnetic map for the region including the South McCullough Mountains Wilderness Study Area with geologic maps of the area (Anderson, 1971; Stewart and Carlson, 1974; Anderson and others, 1985) indicates that the magnetic field in southern Nevada is dominated by anomalies from three main types of sources: (1) Cenozoic volcanic rocks give rise to large-amplitude, relatively short wavelength (roughly 1 mi) positive and negative anomalies that reflect both induced and remanent magnetization in the rocks; (2) Tertiary intrusive rocks produce large-amplitude positive anomalies, generally of somewhat longer wavelength than those over the volcanic rocks; and (3) Proterozoic crystalline rocks are quite variable in their magnetic properties. Some of the Proterozoic rocks, such as the Middle Proterozoic granitic rocks exposed in the northeastern part of the unnamed range 3 mi west of the study area, cause large magnetic anomalies, whereas others, such as the Early Proterozoic granitic and gneissic rocks of the study area, produce at most only low-amplitude anomalies.

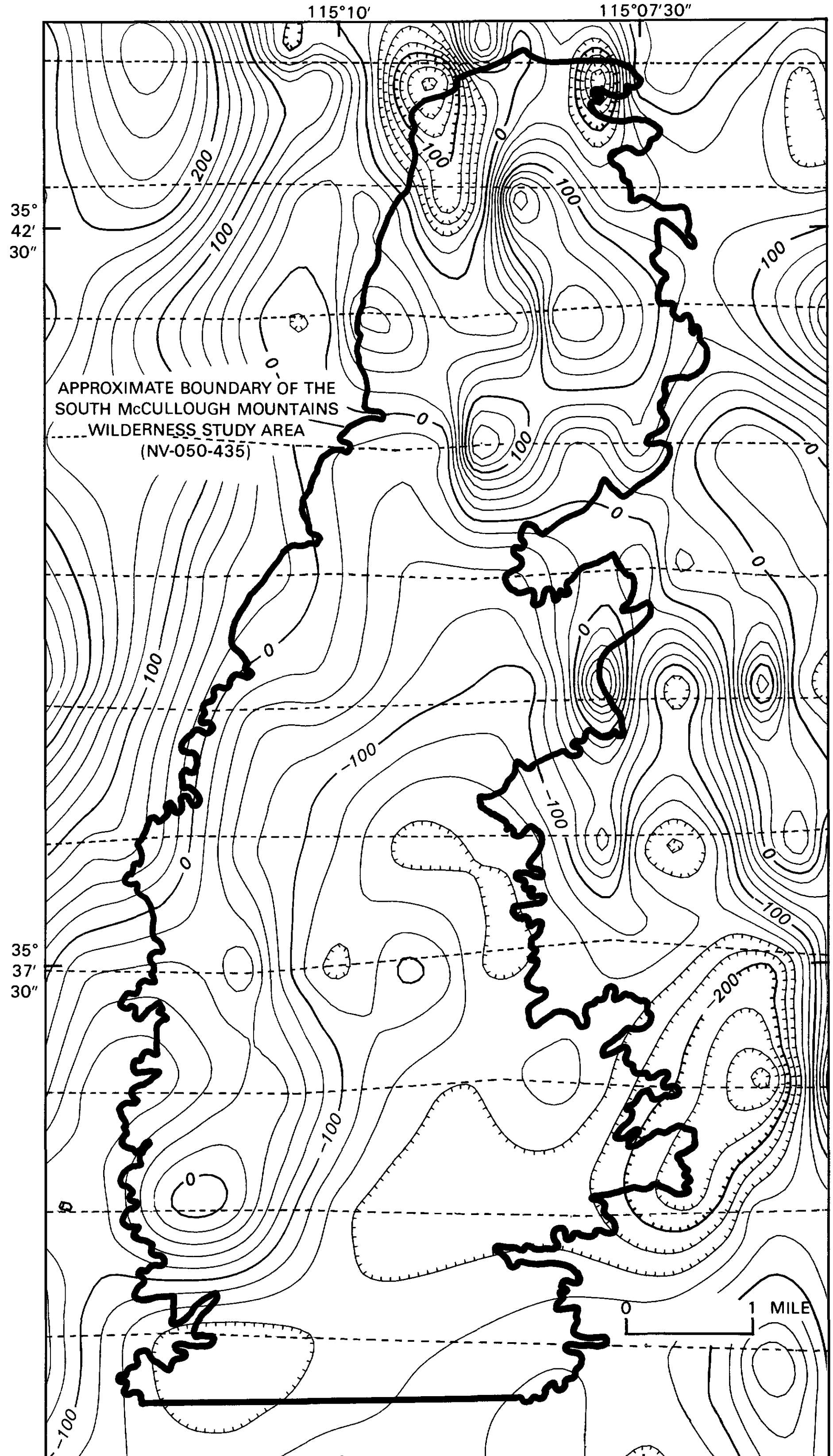
The lack of any large-amplitude magnetic anomalies over the study area having dimensions comparable to those over the Tertiary intrusive bodies to the east suggests that no large magnetic Tertiary intrusive bodies are buried at shallow depth within the study area. However, some Tertiary intrusive rocks of the Searchlight and Eldorado mining districts are only weakly magnetic, and low-amplitude anomalies within the study area could indicate the presence of similar rocks at depth. The narrow, curvilinear magnetic high and gradient that follows the western boundary of the study area for a distance of 3 mi north from McCullough Mountain has roughly the same amplitude as the anomaly over the Crescent district to the south and could reflect a small concealed Tertiary intrusive. Alternatively, this anomaly could be caused by magnetic Proterozoic rocks, but this seems less likely because the anomaly cuts across mapped boundaries within the Early Proterozoic basement.

The magnetic data suggest that Tertiary intrusive bodies that host mineral deposits in the Eldorado and Searchlight mining districts (Longwell and others, 1965) 10 mi east of the study area continue in the subsurface westward toward the study area but probably do not extend beneath it. The magnetic high over the Searchlight district continues to the west as a somewhat linear, 3-mi-wide anomaly for a distance of 15 mi and passes about 5 mi south of the southern boundary of the study area. The western part of this anomaly is coincident with, or within 1 mi of, most of the gold mines and prospects of the Crescent district (Longwell and others, 1965). Although the rocks that host the mineral deposits in the Crescent district are mostly of Early Proterozoic age, the magnetic anomaly could reflect a buried Tertiary intrusive body that served as a source for the mineralizing fluids. The magnetic high over the Eldorado Canyon district extends west of the outcrop of Tertiary intrusive rock but terminates about 7 mi east of the study area.

Radioactivity Survey

Radiometric data from an airborne gamma-ray radioactivity survey that included the McCullough Range were examined because large anomalies in these data coincide with the carbonatite deposit at Mountain Pass, Calif. (25 mi southwest of the study area), which is rich in rare-earth elements (Woyski, 1980). The survey was conducted under contract to the U.S. Department of Energy as part of the National Uranium Resource Evaluation (NURE) program (Western Geophysical Company of America, 1979). For the area that includes Mountain Pass and the McCullough Range, data were collected along east-west flight lines spaced about 3 mi apart and at a nominal height of 400 ft above terrain. Data also were collected along north-south tielines spaced at about 12 mi. The data are presented as radiation in counts per second (cps) for bands characteristic of uranium, thorium, and potassium, and also as total counts per second. Because gamma rays are strongly attenuated by passage through earth materials, these data effectively sample only the uppermost 1.5 ft of the Earth's crust.

The survey line that crosses the Mountain Pass deposit shows strong anomalies in the uranium band (120 cps, or more than five times greater than background), the thorium band (480 cps, or more than four times background), and in total counts per second (12,000 cps, or more than three times background). A moderate anomaly also is apparent in the potassium band (120 cps, or about two times background). No


115°10′
115°07′30″
35°
42′
30″
35°
37′
30″
APPROXIMATE BOUNDARY OF THE
SOUTH McCULLOUGH MOUNTAINS
WILDERNESS STUDY AREA
(NV-050-435)
0
1 MILE
200
100
0
-100
-200

comparable anomalies are found along any of the three east-west flight lines that cross the study area (lines are located at latitudes 35°30′36″, 35°37′48″, and 35°42′36″). These data suggest that no deposits comparable to that at Mountain Pass, Calif., are exposed at the surface beneath the flightlines that cross the study area. They do not, however, preclude the presence of such deposits between flightlines or buried a few feet or more beneath the surface anywhere within the study area.

Landsat Thematic Mapper Data Survey

Part of a Landsat Thematic Mapper (TM) data set covering the study area (scene ID 50044–17424, April 13, 1984) was digitally processed and analyzed to delineate areas of hydrothermally altered, potentially mineralized rocks. A color-ratio-composite (CRC) image was used to identify lithologic information where vegetation did not obscure the outcrops. Generally, vegetation cover greater than 25 percent obscures the spectral signature of the rocks. Rocks containing ferric-iron-oxide minerals, oxyhydride minerals, and sulfate minerals (collectively referred to here as limonite) were distinguished from rocks lacking these components by using a CRC image composed of the band ratios TM3/TM1, TM5/TM4, and TM5/TM7. In addition, rocks containing significant quantities of Fe^{2+}-bearing minerals, such as the varieties of chlorite, were detected. Likewise, rocks containing significant quantities of hydroxyl-bearing (OH-rich) sheet silicates (such as clays and micas) were distinguished from rocks lacking these attributes. Hydrothermally altered rocks commonly contain an abundance of sheet silicate minerals and (or) ferric-iron-bearing minerals.

Anomalous areas identified on the TM CRC image are listed in table 3 and noted on plate 1. They are referred to in table 3 by location in the township and range system. Several small areas located just outside (within 1 mi) of the study area boundary are included. Most anomalous areas defined by the remote sensing data were visited in the field. Those recognized in the image data after the field investigation were not field checked, and their interpretation is highly speculative. Field checking is important because some crystalline rocks may produce anomalous signatures due to processes other than hydrothermal alteration. Such false anomalies are caused by supergene weathering of the ferromagnesian minerals, which produces both hematite and goethite, and by the presence of large quantities of micas as original constituents.

Altered rocks within the study area are in very small scattered patches except within the area encompassed by anomalies I and III (pl. 1). Anomalies I-III are underlain by granitic gneiss and minor amounts of amphibolite, both of which are cut by younger granitic dikes. These areas contain much hematite and goethite; quartz veins within the area contain goethite pseudomorphs after pyrite that are similar to pseudomorphs in the Crescent mining district a few miles to the south. In some places feldspars in the rocks have been altered to clay minerals. Minor silicification was noted in the darker rocks of area III. The alteration may in some fashion be structurally controlled, as suggested by the rather linear trace of the main northeast-trending stream that drains the area of anomaly I. These areas also lie on a strong aeromagnetic gradient (fig. 3). However, the gradient may only reflect the presence of Tertiary intermediate to mafic volcanic rocks to the north and their lack to the south (pl. 1). Stream-sediment samples, which were not collected in this area, would provide a test for associated geochemical anomalies and mineralized material.

Figure 3 (facing page). Residual total-intensity aeromagnetic anomaly map of the South McCullough Mountains Wilderness Study Area, Clark County, Nev. Contour interval 20 gammas. Hachures indicate direction of decreasing magnetic intensity. East-west flight-line spacing 1 mi. Heavy solid line is approximate boundary of study area. Data from U.S. Geological Survey (1979).

Mineral and Energy Resource Potential

The mineral resource potential in the South McCullough Mountains Wilderness Study Area is summarized in figure 2 and plate 1. In the text and in tables in figure 2, on plate 1, and in table 4, metals are listed in decreasing order of importance or concentration.

Metallic Mineral Resources

All of the South McCullough Mountains Wilderness Study Area, excluding those numbered areas that are discussed below and are shown on figure 2 and plate 1, and the part covered by Tertiary volcanic rocks, has a low mineral resource potential (certainty level C) for zinc, copper, silver, and gold in medium-size to small stratabound, syngenetic deposits in high-grade Early Proterozoic gneiss (unit Xgn). Protoliths of the gneiss were siltstone, aluminous sedimentary rocks, and impure feldspathic sediments, similar to country rocks in the Belt Supergroup near the Sullivan mine in British Columbia (Freeze, 1966; Ethier and others, 1976; Campbell and others, 1978) and to wallrocks of the Willyama Supergroup near the Broken Hill mine in southeastern Australia (King and Thompson, 1953; Willis and others, 1983; Wright and others, 1987). The likelihood of stratabound deposits of this type in the study area is low due

Table 3. Summary of anomalous areas determined from Landsat Thematic Mapper data for the South McCullough Mountains Wilderness Study Area, Clark County, Nev.

Number on pl. 1	Location	Anomaly	Interpretation
I	E 1/2 of Sec. 21, W 1/2 of Sec. 22, T. 26 S., R. 61 E.	Limonitic, OH-rich rocks.	Patchy hematitic alteration of granitic gneiss and granitic intrusive rocks; limonite psuedomorphs after pyrite in massive quartz.
II	N 1/2 of NW 1/4 of SE 1/4 of SW 1/4 of Sec. 21, T. 26 S., R. 61 E.	Nonlimonitic, OH-rich rocks.	Relatively bright rocks showing strong OH absorption. Possible clay alteration. Not field checked.
III	NE 1/4 of Sec. 27, T. 26 S., R. 61 E.	Limonitic rocks or Fe^{2+}-rich rocks rich in OH.	Relatively dark crystalline rocks containing limonite and quartz. Hydrothermally altered crystalline rocks in which feldspars altered to clays.
IV	SW 1/4 of NE 1/4 of Sec. 26, T. 26 S., R. 61 E.	Limonitic rocks or Fe^{2+}-rich rocks rich in OH.	Relatively dark crystalline(?) rocks containing limonite and clays(?). Not field checked, but spectral signature similar to anomaly III.
V	SW 1/4 of SW 1/4 of Sec. 6, T. 27 S., R. 61 E. and NE 1/4 of NE 1/4 of Sec. 12, T. 27 S., R. 60 E.	Limonitic rocks or Fe^{2+}-rich rocks rich in OH.	Limonite-rich granitic rocks in which feldspars altered to clays; some silicification.
VI	NW 1/4 of Sec. 19, T. 25 S., R. 61 E.	Limonitic rocks or Fe^{2+}-rich rocks; some are bleached, all rich in OH.	Fine-grained crystalline rocks containing minor limonite; sericite present locally.
VII	N 1/2 of SE 1/4 of Sec. 3, T. 27 S., R. 61 E.	Nonlimonitic rocks rich in OH, or weak in OH but rich in CO_3.	Relatively bright nonlimonitic rocks rich in OH; possible clay alteration. Not field checked.

to the lack of recognized mineralized horizons and the lack of anomalous concentrations of base metals in stream-sediment concentrates.

The area also has a low potential (certainty level C) for niobium, tantalum, uranium, thorium, rare-earth elements, and pegmatite minerals in late-stage pegmatite bodies and granite. Numerous simple pegmatite bodies are known (parts of units Xgg and Xgr, pl. 1), but few contain highly anomalous concentrations of the above elements or minerals.

Table 4. Summary of areas having mineral resource potential in and adjacent to the South McCullough Mountains Wilderness Study Area, Clark County, Nev.

[Commodities listed in order of relative importance; commodities underlined are considered to be byproducts or trace metals that could be recovered if deposits containing principal metals were mined; where variable sizes of deposits are shown, the most probable size is listed first; size of deposits listed below; <, less than]

Map area (pl. 1 and fig. 2)	Resource potential	Level of potential/ level of certainty (see Appendix for explanation of symbols)	Commodities (listed in order of importance)	Size, type of deposit
All, except numbered areas below and part covered by Tertiary volcanic rocks	Low	L/C	Zn, Cu, Ag, Au	Medium to small, stratabound
	Low	L/C	Nb, Ta, U, REE, Th	Small, pegmatite bodies
	Unknown	U/A	Au, Ag	Small to medium, breccia pipe
1	Unknown	U/A	Au, Ag, Pb,, Cu	Small, vein
	Unknown	U/A	Au, Ag, Pb, Zn, Cu, As	Small, vein or breccia pipe
	Unknown	U/A	La, REE, U, Th, Nb	Medium, carbonatite bodies and dikes
	Unknown	U/A	W, Cu	Small, vein
2	Low	L/B	Sn	Small, vein
3	Moderate	M/C	Ag, Au, Pb, Cu, Zn	Small, vein
	Moderate	M/B	La, REE, U, Th, Nb	Medium, carbonatite bodies and dikes
4	Low	L/C	W, Cu	Small, vein
5	Moderate	M/C	La, REE, U, Th, Nb	Medium, carbonatite bodies and dikes
6	Moderate	M/D	W, Cu	Small to medium, vein
7	Moderate	M/B	Ag, Au	Small, vein or breccia pipe
8	Low	L/C	Cu, Au, Ag, As	Small, vein

Small vein deposit = <10,000 tons
Medium-size vein deposit = 10,000-250,000 tons
Small stratabound deposit = <5 million tons
Medium-size stratabound deposit = 5 million-50 million tons
Small pegmatite deposit = <30,000 tons
Small breccia pipe deposit = <5 million tons
Medium-size breccia pipe deposit = 5 million-20 million tons
Medium-size carbonatite deposit = 5 million-20 million tons

The resource potential for gold and silver in small to medium-size epithermal veins and breccia pipes throughout the study area is difficult to assess. Breccia pipes containing gold and silver are one of the most common deposit types in this part of the Mojave Desert; they are present in the Ivanpah Mountains and Clark Mountain Range, west of the McCullough Range (Hewett, 1956; Durning and Hillemeyer, 1986; DeWitt, 1987), and in the New York Mountains to the south (Longwell and others, 1965; Miller and others, 1986). However, the small size of the pipes, their low concentrations of precious metals (gold and silver), and the general lack of placer gold downstream from the pipes make detection of the deposits difficult. Because stream-sediment concentrates in this study were analyzed semiquantitatively (20 ppm detection limit for gold; 1 ppm detection limit for silver), small and (or) low-grade breccia pipes could go undetected in the study area. Therefore, we conclude that all of the study area, excluding those numbered areas that are discussed below and are shown on figure 2 and plate 1, and the part covered by Tertiary volcanic rocks, has an unknown potential (certainty level A) for gold and silver in small to medium-size breccia pipes of Mesozoic and early Tertiary age.

The six areas numbered 1 on plate 1 have an unknown resource potential (certainty level A) for gold, silver, lead, and copper in small vein deposits of Tertiary age (table 4) and gold, silver, lead, zinc, copper, and arsenic in small vein deposits or breccia-pipe deposits of Proterozoic to Laramide (latest Cretaceous to early Tertiary) age. These areas also have an unknown resource potential (certainty level A) for lanthanum and other rare-earth elements, uranium, thorium, and niobium in small to medium-size carbonatite deposits in veins and dikes of Middle Proterozoic age, and an unknown resource potential (certainty level A) for tungsten and copper in small vein deposits of Proterozoic to late Mesozoic age. Knowledge of the rock types and structures present in the area is not considered sufficient, without geochemical control, for an assessment other than that of "unknown mineral resource potential." All areas on plate 1 that are numbered 1 lack stream-sediment-sample coverage, and lie outside of drainage basins and geochemical sites that were selected to achieve high sensitivity for the major part of the study area upstream. We consider the geochemical data to be an integral part of the geologic information necessary for an assessment of mineral resource potential; without that data we do not feel that an assessment other than "unknown" can be made for these areas. Geochemical data are especially necessary for detecting small, but very high grade deposits such as carbonatite dikes, and small, but very low grade deposits such as breccia pipes.

The northernmost of the six areas having unknown resource potential extends from McClanahan Spring along the western boundary to the northern boundary of the study area and straddles one of the largest Tertiary faults in the area. East of this area, on the eastern boundary, is a small area in Tertiary volcanic rocks. A large area extending from southeast of McClanahan Spring to north of McCullough Spring is underlain by Early Proterozoic gneiss and various types of Early Proterozoic granite. A fourth area northeast of McCullough Mountain and adjoining the boundary of the study area is underlain by bedrock consisting of Early Proterozoic gneiss and minor plutonic rocks. The fifth area, in the far southeastern corner of the study area, east of Pipe Spring, and the sixth area, southwest of McCullough Mountain, along the boundary of the study area, are underlain by bedrock that is predominantly Early Proterozoic gneiss.

Area 2, in Tertiary volcanic rocks north of McCullough Spring, has a low potential (certainty level B) for tin resources in small vein deposits of Tertiary age. A stream-sediment concentrate containing 20 ppm tin (sample MH006; pl. 1) indicates low-grade mineralized material somewhere in the drainage basin defined as area 2. Geologically, the source of the tin is unknown and geophysical information gives no indication of the source. Because most of the volcanic rocks in the area are basalt, a likely source of the tin is mineralized material along a high-angle fault.

Two areas numbered 3 (pl. 1) have a moderate resource potential (certainty level C) for silver, gold, lead, copper, and zinc in small vein deposits of Proterozoic to Tertiary age. Both these areas are near the center of the western boundary of the study area and surround known mineralized quartz veins at the Breyfogle and Hacienda prospects (Hewett, 1956; Close, 1987). Steep quartz veins trend parallel to Early Proterozoic foliation at the Breyfogle prospect, but perpendicular to foliation at the Hacienda prospect; the deposits could be of radically different ages. Stream-sediment concentrates from sample MH026 (pl. 1; H.N. Barton, unpub. data, 1986) did not reflect mineralized material from the Breyfogle prospect, located less than 1 mi upstream and in a drainage basin of approximately 1 mi^2. Small deposits containing low concentrations of gold and silver may be undetected by the methods of analysis used in this regional geochemical survey. The available geophysical data are not helpful in further defining areas of resource potential for these types of deposits. The two areas also have a moderate resource potential (certainty level B) for lanthanum and other rare-earth elements, uranium, thorium, and niobium in carbonatite bodies similar to those discussed for area 5 below.

Area 4, upstream from McCullough Spring, has a low resource potential (certainty level C) for tungsten and copper in small vein deposits of Proterozoic to late Mesozoic age. An anomalous concentration of tungsten (200 ppm) in the concentrate from stream-sediment sample MH013 (pl. 1) indicates mineralized material, probably along northeast-striking quartz veins, in area 4. These tungsten-bearing veins are probably similar in age and genesis (Early Proterozoic, related to hornblende quartz diorite or migmatitic leucogranite emplacement) to veins discussed in area 6, below.

Area 5, on the western side of the study area, has a moderate resource potential (certainty level C) for lanthanum and other rare-earth elements, thorium, uranium, and niobium in carbonatite deposits in veins and dikes that may exist in the subsurface. The possible existence of these deposits at depth is supported by anomalous concentrations of calcium (50 percent in stream sediment concentrate MG011), lanthanum (700 ppm in MA011), yttrium (1,000 and 2,000 ppm in MH024 and MH025, respectively), and scandium (50 ppm in MA010) from stream sediments west of the study area (pl. 1). Deposits of this sort would be similar to those at the Mountain Pass mine in the Clark Mountain Range (Olson and others, 1954). There, carbonatite bodies and related rare-earth mineralization are temporally related to emplacement of Middle Proterozoic, 1,400-Ma shonkinitic, syenitic, and granitic stocks and dikes (Olson and others, 1954; DeWitt, 1987; DeWitt and others, 1987). A large Middle Proterozoic pluton, informally referred to as the "syenogranite of Beer Bottle Pass" (Anderson, in press) is exposed in the unnamed range just southwest of McClanahan Spring. Because rocks northwest of the study area were not mapped as part of this investigation, we cannot say how close to the study area dikes and satellitic bodies of this pluton may extend. However, aeromagnetic data (fig. 3) suggest that parts of the buried pluton may extend beneath the study area. If the syenogranite of Beer Bottle Pass is spatially related to carbonatite dikes or veins, some mineralized material containing high concentrations of rare-earth elements could be present in the subsurface of area 5.

The two areas numbered 6 (fig. 2 and pl. 1) have a moderate resource potential (certainty level D) for tungsten and copper in small to medium-size quartz-vein deposits related either to (1) emplacement of hornblende quartz diorite (unit Xd), or (2) emplacement of migmatitic leucogranite (part of unit Xgg). The quartz-scheelite-malachite vein deposit at the War Lord prospect, just outside the study area boundary (Close, 1987; this report), is typical of deposits that might exist in the study area. Anomalous concentrations of tungsten in stream-sediment samples from the study area were noted in MA004 (700 ppm) and MH018 (500 ppm; pl. 1). Although the age of the vein deposit at the War Lord prospect is undetermined, we assume that it is Early Proterozoic and related either to emplacement of hornblende quartz diorite or leucogranite. A pronounced aeromagnetic low (–100 gammas) is present over the northeastern part of area 6 outside the study area (fig. 3). The low could indicate a relatively large body of migmatitic leucogranite at depth beneath much of area 6 that is related to the development of quartz veins and tungsten mineralization. A much larger aeromagnetic low (–240 gammas) to the south-southeast (fig. 3) may be partly a function of this body of migmatitic leucogranite and be caused partly by a north-northwest-trending high-angle Tertiary normal fault.

Area 7, east of McCullough Mountain, has a moderate resource potential (certainty level B) for silver and gold in small vein deposits of Proterozoic to Tertiary age or in small breccia-pipe deposits of Laramide age. Such breccia pipes would be similar to the Colosseum mine in the Clark Mountain Range (Hewett, 1956; Durning and Hillemeyer, 1986) or the Lucy Grey mine in the unnamed range west of the McCullough Range (Hewett, 1956). Anomalous concentrations of silver in a stream-sediment concentrate (MH019, 5.0 ppm Ag; pl. 1) indicate mineralized material somewhere in the drainage basin outlined by area 7. The source of the mineralized material is unknown; either a small vein or breccia pipe are likely. The available geophysical information is not helpful in further defining the extent of mineralized material.

Two areas numbered 8 (fig. 2 and pl. 1) have a low resource potential (certainty level C) for copper, gold, silver, and arsenic in small vein deposits of Proterozoic to Tertiary age. The two areas are in the southwestern corner of the study area, south and west of McCullough Mountain. Vein deposits that may exist in these areas would be similar to those at the Silver King prospect and prospects at E, F, G, and H (table 1, fig. 2, and pl. 1) (prospects 5, 6, 7, and 8 in Close, 1987). A small aeromagnetic high (+60 gammas) is centered over the northern part of the two areas. This high could be caused by a number of geologic features, the most likely of which are a buried, slightly magnetite-enriched part of hornblende quartz diorite (unit Xd), a small plug of Middle Proterozoic granite related to the syenogranite of Beer Bottle Pass, or a magnetite-rich horizon in the Early Proterozoic gneiss (unit Xgn).

Areas adjacent to the study area that have anomalous concentrations of metals in stream-sediment concentrates include (1) a small drainage basin northwest of Railroad Spring (off pl. 1, but approximate location indicated) that contains 7,000 ppm barium and 1,500 ppm yttrium (sample MA009; pl. 1); and (2) small drainage basins northeast of McCullough Spring that contain 300 ppm thorium and 500 ppm lead (samples MH016 and MG002, respectively; pl. 1). These two drainage basins are interesting because they are entirely within Tertiary volcanic rocks, predominantly basalt, and were not expected to contain anomalous concentrations of the above elements.

Energy Resources

The McCullough Range has been stripped of its cover of Paleozoic and Mesozoic strata, and there is no indication that these strata underlie the Early Proterozoic crystalline rocks at depth. Therefore, the study area has no resource potential (certainty level D) for oil and gas or coal. The area has a low potential for geothermal resources, at certainty level C. No faults or hydrothermally altered areas exist that would suggest the presence of low- or high-temperature fluids.

Other Commodities and Deposit Types

The study area contains significant amounts of sand and gravel, especially along streams that drain to the east, toward the Highland Range. This material is very poorly sorted and contains many cobbles and boulders. The area has only a low resource potential (certainty level C) for undiscovered sand and gravel that would meet commercial specifications. Granite and bodies of pegmatite that are widespread in the area could be exploited for dimension stone and pegmatite minerals (feldspar and mica), but larger and higher grade deposits are known outside the area. Therefore, the area has only a low resource potential (certainty level C) for undiscovered resources of dimension stone, feldspar, and mica.

Recommendations for Further Study

In order to more properly assess the mineral resource potential for gold and silver in small epithermal veins and breccia pipes, stream-sediment concentrates need to be analyzed quantitatively for low levels of these precious metals. Techniques applicable to exploration for disseminated gold in Carlin-type deposits (Roberts and others, 1971; Radtke and others, 1980; Northrop and others, 1987) in Nevada should be employed for rocks in the McCullough Range.

The proximity of the McCullough Range to the world's largest source of light rare-earth elements at Mountain Pass, Calif., necessitates completion of a thorough evaluation of the potential for carbonatite deposits in the study area. Surface expressions of minor fractures, faults, and shear zones that could contain carbonatite dikes or mafic rocks need to be more quantitatively assessed. This could be accomplished by more detailed stream-sediment sampling programs in which the heavy minerals, especially apatite and other phosphate minerals, are analyzed by cathodoluminescence techniques (Mariano and Roeder, 1987). A detailed aeromagnetic survey at a flight-line spacing of 0.25 mi should be conducted over the Early Proterozoic core of the range in order to assess the likelihood of buried bodies of mafic, magnetic rock such as shonkinite and nepheline syenite and nonmagnetic bodies of carbonate rock. A ground-based gravity survey over selected parts of the study area would help to define anomalies that could be caused by dense rock types such as carbonatite and shonkinite.

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APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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

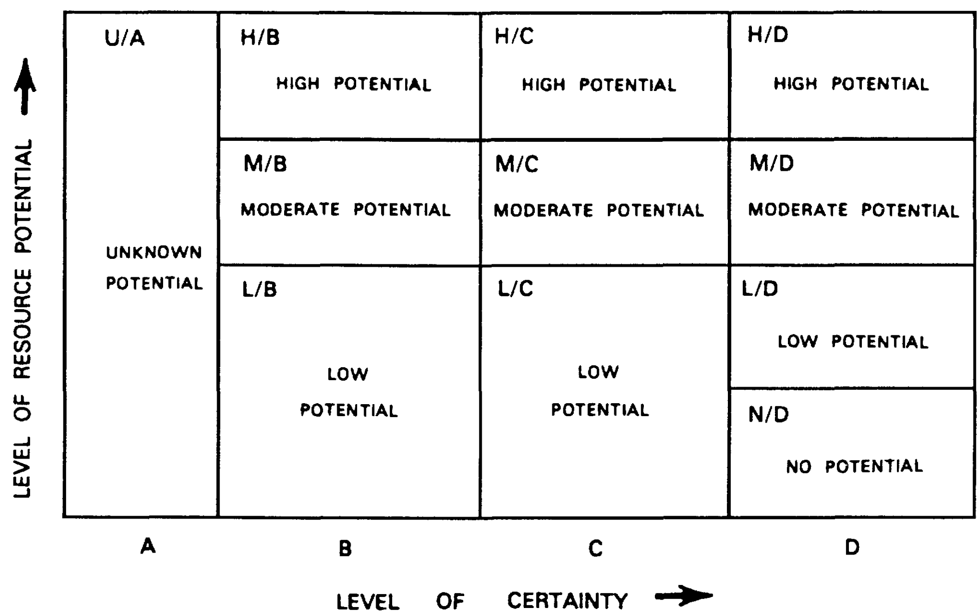
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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

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

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

Levels of Certainty



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

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RESOURCE/RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (or)	
	Measured	Indicated		Hypothetical	Speculative
ECONOMIC	Reserves		Inferred Reserves		
MARGINALLY ECONOMIC	Marginal Reserves		Inferred Marginal Reserves		
SUB-ECONOMIC	Demonstrated Subeconomic Resources		Inferred Subeconomic Resources		

Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from 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.

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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