Mineral Resources of the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas, San Bernardino County, California

U.S. GEOLOGICAL SURVEY BULLETIN 1713-D

Chapter D

Mineral Resources of the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas, San Bernardino County, California

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MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
EASTERN CALIFORNIA DESERT CONSERVATION AREA, CALIFORNIA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
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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 U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine their mineral resource potential. Results must be made available to the public and be submitted to the President and the Congress. This report summarizes the results of a mineral survey of the Whipple Mountains (CDCA–312) Wilderness Study Area, California Desert Conservation Area, and the Whipple Mountains Addition Wilderness Study Area (AZ–050–010), San Bernardino County, California.

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SUMMARY

Abstract

At the request of the U.S. Bureau of Land Management, approximately 85,100 acres of the Whipple Mountains Wilderness Study Area (CDCA–312) and 1,380 acres of the Whipple Mountains Addition Wilderness Study Area (AZ–050–010) were evaluated for identified mineral resources (known) and mineral resource potential (undiscovered). In this report, the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas are referred to as simply "the study area."

Most of the mines and prospects with identified resources in the Whipple Mountains Wilderness Study Area are within areas designated as having mineral resource potential. The area in and around the Turk Silver mine and the Lucky Green group and the area near the northwest boundary of the study area have high mineral resource potential for copper, lead, zinc, gold, and silver. An area along the west boundary of the study area has moderate resource potential for copper lead, zinc, gold, and silver. An area in the east adjacent to the Whipple Mountains Addition Wilderness Study Area has moderate resource potential for copper, gold, and silver resources. One area on the north boundary and one on the southeast boundary of the study area have low mineral resource potential for copper, lead, zinc, gold, and silver. Two areas, one on the north boundary and one inside the east boundary of the study area, have moderate resource potential for manganese. A small area inside the south boundary of the study area has high resource potential for decorative building stone, and the entire study area has low resource potential for sand and gravel and other rock products suitable for construction. Two areas in the eastern part of the study area have low resource potential for uranium. There is no resource potential for oil and gas or geothermal resources in the Whipple Mountains Wilderness Study Area.

Sites within the Whipple Mountains Wilderness Study Area with identified resources of copper, gold, silver, manganese and (or) decorative building stone are located at the Stewart mine, New American Eagle mine, Turk Silver mine, Twin Lode mine, decorative stone property, Lucky Green group, Blue Cloud mine, Nickel Plate mine, Crescent mine, Quadrangle Copper group, and the Copper Basin mine.

The Whipple Mountains Addition Wilderness Study Area has moderate resource potential for copper, gold, and silver resources and low resource potential for sand and gravel and other rock products. There is no resource potential for oil and gas or for geothermal energy in the Whipple Mountains Addition Wilderness Study Area.

Although there are no identified resources in the Whipple Mountains Addition Wilderness Study Area, sites within and immediately adjacent warrant further study because of gold assays from widespread, numerous samples.

Character and Setting

The Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas (fig. 1) encompass 86,480 acres in southwestern San Bernardino County, Calif. (U.S. Department of the Interior, Bureau of Land Management, 1980). The study area is located on the east edge of the Mojave Desert 6 mi northwest of Parker, Ariz., and 10 mi south of Lake Havasu City, Ariz., and encompasses a major part of the Whipple Mountains. Major access to the area is from California Highway 62 to the south and from a paved road on the west side of the

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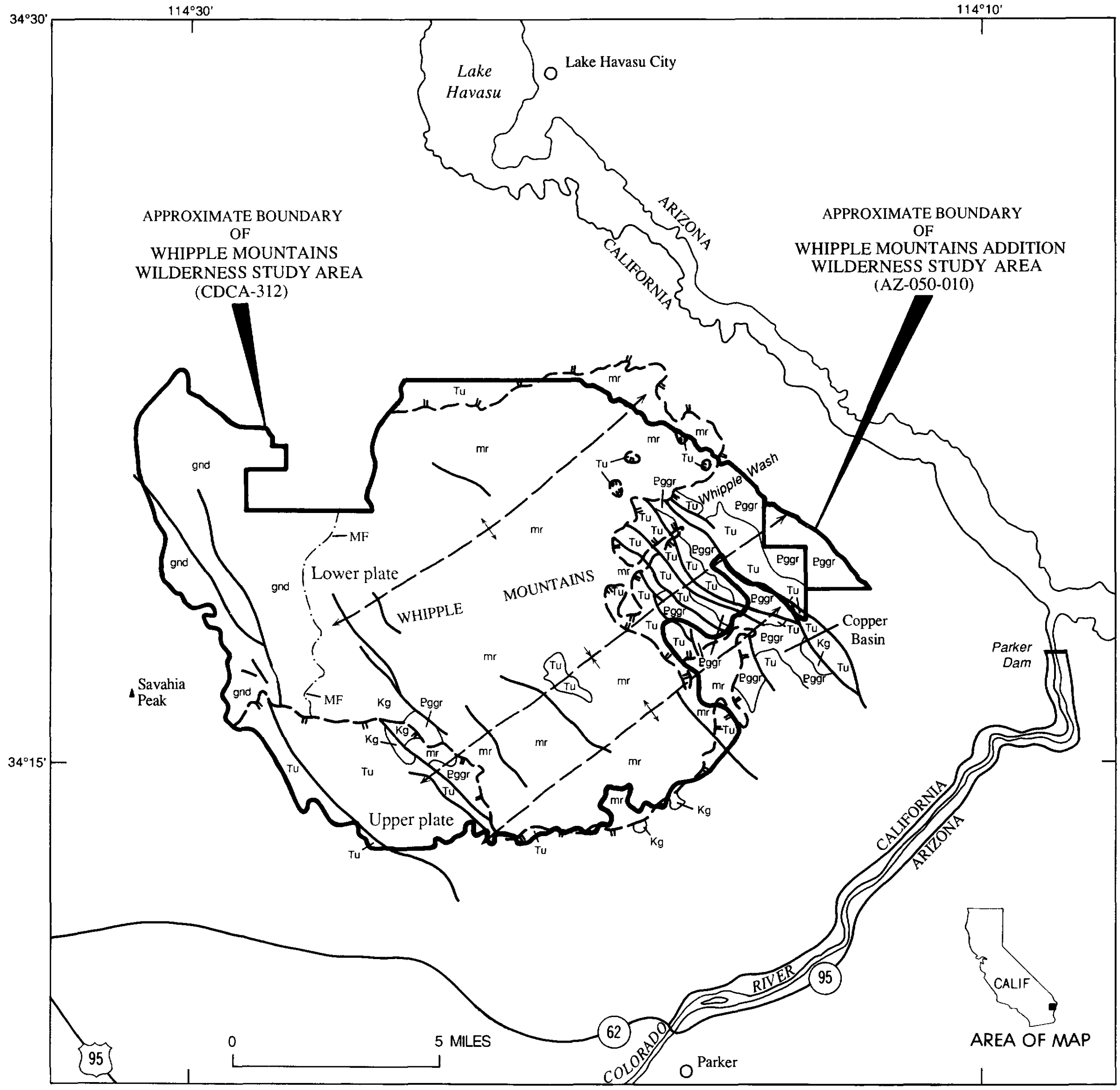
Colorado River. The local topography is dominated by the Whipple Mountains, which rise from 1,200 ft along the south border of the area to an elevation of 4,131 ft above sea level in the central part of the area. The terrain is rugged with sloping flanks to the south and precipitous faces to the north.

Identified Resources in the Whipple Mountains Wilderness Study Area

None of the properties with identified resources in the Whipple Mountains Wilderness Study Area appear to be economically minable at the average 1986 prices of gold,



EXPLANATION

Geologic Map Units

Tu	Tertiary volcanic and sedimentary rocks
Kg	Cretaceous granodiorite rocks
mr	Tertiary, Cretaceous and Proterozoic mylonitic rocks
gnd	Proterozoic gneiss with subordinate Tertiary, Cretaceous, and Proterozoic granitoid rocks and Tertiary dikes
Pggr	Proterozoic granitoid rocks and gneiss

Contact

Fault

Whipple Mountains detachment fault—Hachures on upper plate

MF Mylonitic front

Antiform—Showing direction of plunge

Synform—Showing direction of plunge

Figure 1. Index map showing location and generalized geology of the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas, San Bernardino County, California.

silver, copper, and manganese. The Copper Basin mine just outside the study area is the most likely property to be developed. The highest grade deposit, immediately adjacent to the study area, is the Crescent mine (fig. 3 and tables 1 and 2, No. 43) which has a 17,000-ton resource that is estimated to contain 0.14 ounces per ton (oz/t) gold, valued at approximately \$59/t (gold = \$424/oz), and 2.4 percent copper, valued at \$36/t (copper = \$0.77/lb), for a total unit value of \$95. However, because of the estimated production costs, the resources at the Crescent mine are subeconomic at the commodity prices specified. Despite the economics of mining at the average 1986 prices of copper and gold, further investigation at four other copper-gold properties would be justified. The properties are the War Eagle mine (outside study area) and the Sleepy Burro group, New American Eagle mine, and the Copper Crest group within the study area (fig. 3 and tables 1 and 2, Nos. 2, 3, 4, and 46). All of these properties are located on or near large faults or fault systems that provided major avenues for movement of hydrothermal solutions.

Selective mining of manganese outcrops and stoping of underground pods at the Monarch, Manganese King, and Monument King mines (fig. 3 and table 2, Nos. 37, 38, and 39) could yield small quantities of manganese. If the Federal Government institutes a manganese purchase program to build stockpiles of this strategic metal, further exploration of these mines would be warranted. Voluminous occurrences of common borrow, sand, and gravel are in Quaternary alluvium (see geologic time chart in appendixes) in canyons and drainages radiating from the core of the study area; however, most of these occurrences are outside of the study area at lower elevations. Because of the high-bulk low unit value of the alluvium and the high transportation costs involved in shipping to distant markets, development is unlikely in the foreseeable future other than for local uses. These same influences of market outlets (demand), low unit value, and high transportation costs also affect the minability of identified decorative stone within the study area.

Identified Resources in the Whipple Mountains Addition Wilderness Study Area

Because the workings at most sites examined were unsafe to enter and the structures exposed by them discontinuous, no resources were identified. However, 46 samples collected from six sites within and immediately adjacent to the Whipple Mountains Addition Wilderness Study Area contain gold that ranges from a trace to 1.56 oz/t; most samples contain less than 0.1 oz/t. In view of the substantial increase in gold mining in the western states during the past 10 years, these factors suggest that the sites warrant further exploration. Voluminous occurrences of common borrow, sand, and gravel are in Quaternary alluvium in and near the Whipple Mountains Addition Wilderness Study Area; however, most of these occurrences are outside of the study area at lower elevations. Because of the high-bulk low unit value of the alluvium and the high transportation costs involved in shipping to distant markets, development is unlikely in the foreseeable future other than for local uses.

Mineral Resource Potential of the Whipple Mountains Wilderness Study Area

There are 12 areas of mineral resource potential within the Whipple Mountains Wilderness Study Area (fig. 2). These are broadly grouped into seven types: (1) copper, gold, and silver with or without lead and zinc in the upper plate of the Whipple Mountains detachment fault (high and moderate mineral resource potential), (2) copper, lead, zinc, gold, and silver in the lower plate of the Whipple Mountains detachment fault (high, moderate, and low mineral resource potential), (3) copper, lead, zinc, gold, and silver mineralization related to granitic plutons (low mineral resource potential), (4) manganese related to Tertiary volcanic rocks (moderate mineral resource potential), (5) undiscovered decorative stone adjacent to measured resources of decorative stone (high mineral resource potential), (6) sand and gravel and other rock products throughout the area (low mineral resource potential), and (7) uranium in Tertiary lake-bed sediments (low mineral resource potential). The study area has no resource potential for oil and gas or geothermal energy.

Most of the known mineralization in the Whipple Mountains Wilderness Study Area occurs in, or is closely related to, the upper plate and chlorite breccia zone of the Whipple Mountains detachment fault, with the exception of mineralization in the lower plate rocks on the west and north sides of the area (fig. 2). There mineralization appears more related to near-surface dike swarms localized along late normal faults that cut both upper and lower plate rocks. Geochemically the mineralized zones in the study area indicate an elemental metal suite of copper, lead, and zinc with copper predominating. Gold and silver are associated with this suite, with variations in concentration from area to area. Barium is ubiquitous in both upper and lower plate rocks close to the detachment fault surface but diminishes away from it. This supports the concept of redistribution of minerals by rain and (or) hydrothermal waters along the detachment fault. Manganese appears exclusively associated with Tertiary volcanic rocks in the upper plate and with alteration. The conceptual model for mineralization in the study area is a low- to moderate-temperature hydrothermal system spatially related to the detachment fault and chlorite breccia zone immediately below it. Most or all of the initial mineralization probably occurred prior to detachment faulting, with conduction of fluids and redistribution of minerals provided by fault conduits formed during dislocation of the upper plate. Volcanism could also have provided a source of metallic elements, especially manganese, in addition to providing heat and hydrothermal fluids.

Mineral Resource Potential of the Whipple Mountains Addition Wilderness Study Area

There are two areas of mineral resource potential within the Whipple Mountains Addition Wilderness Study Area (fig. 2). These are grouped into two types: (1) copper,

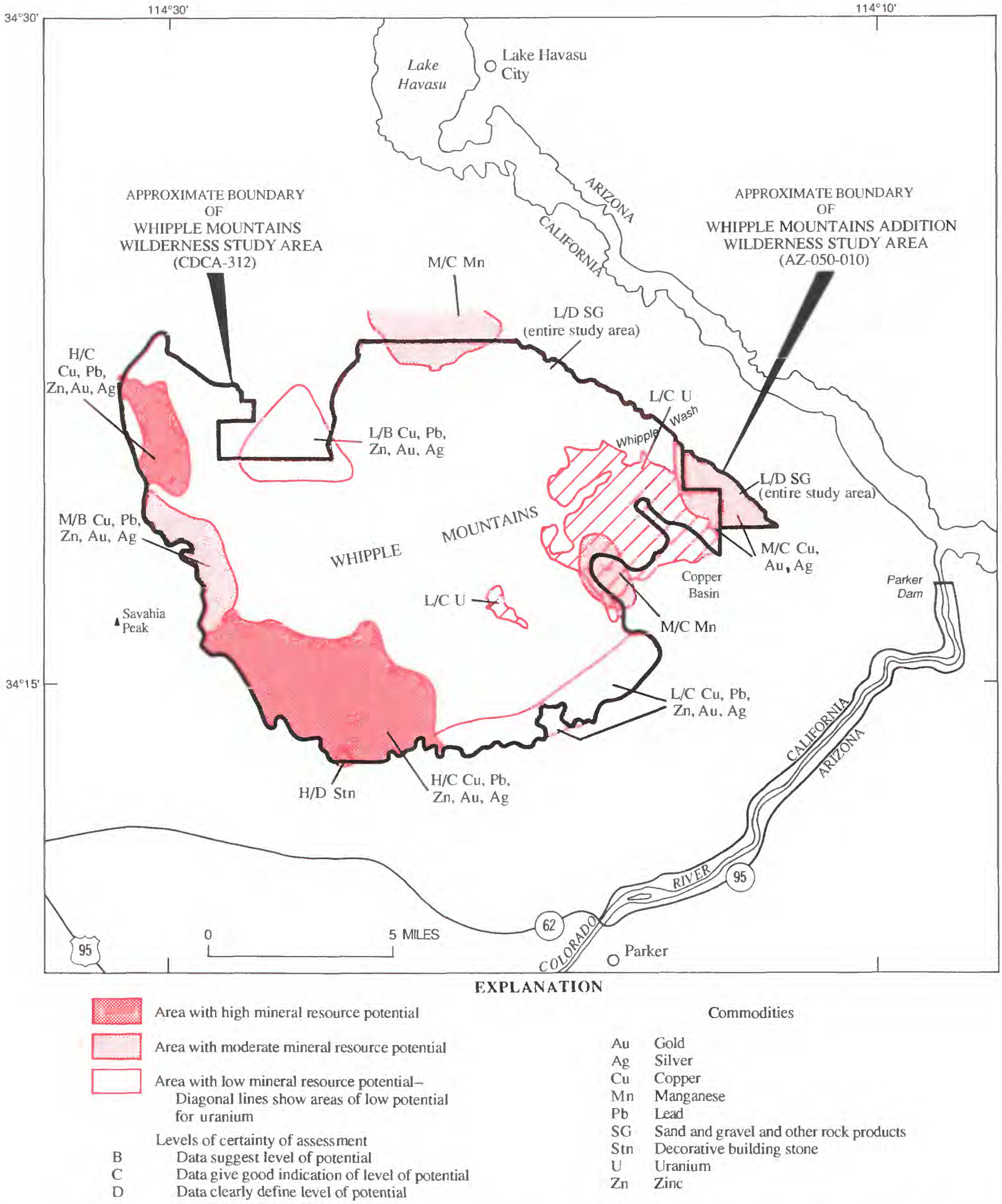


Figure 2. Mineral resource potential of the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas, San Bernardino County, California.

Table 1. Identified subeconomic resources in and near the Whipple Mountains and Whipple Mountain Addition Wilderness Study Areas, San Bernardino County, California

Map No. (fig. 3)	Name	Tons	Commodities
1	Stewart mine	[1]2,600	12 percent to 15 percent manganese
*4	New American Eagle mine	[2]2,075	3.8 percent to 4.17 percent copper
13	Turk Silver mine	2,000	2.4 oz/ton silver, 0.6 percent copper
14	Twin Lode mine	4,100	7.0 oz/ton silver, 0.1 percent copper
15	Decorative stone property	1,000	Weather-face stone
		10,000	Split-face stone
20	Lucky Green group	1,950	0.32 percent copper
*27	Blue Cloud mine	235,000	0.48 percent copper
*33	Nickel Plate mine	3,000	0.02 oz/ton gold, 1.4 percent copper
*43	Crescent mine	17,000	0.14 oz/ton gold, 2.4 percent copper
*45	Copper Basin mine	[3]7–11 million	1 percent to 2 percent copper
48	Quadrangle Copper group	16,000	2 percent copper

*Outside study area.
[1]Long tons.
[2]Reported by Wilson (1918).
[3]Reported by Dravo Corp. (1974).

gold, and silver in gneiss (moderate mineral resource potential) and (2) sand and gravel and other rock products (low mineral resource potential). The Whipple Mountains Addition Wilderness Study Area has no resource potential for oil and gas or geothermal energy.

Sand and gravel are present in the Whipple Mountains Addition Wilderness Study Area in alluviated washes and fans, and these products can also be found outside the study area boundary. The Whipple Mountains Addition Wilderness Study Area is underlain by gneiss that has been intruded locally by dikes and coarse-grained granitic rocks, all in the upper plate of the Whipple Mountains detachment fault.

INTRODUCTION

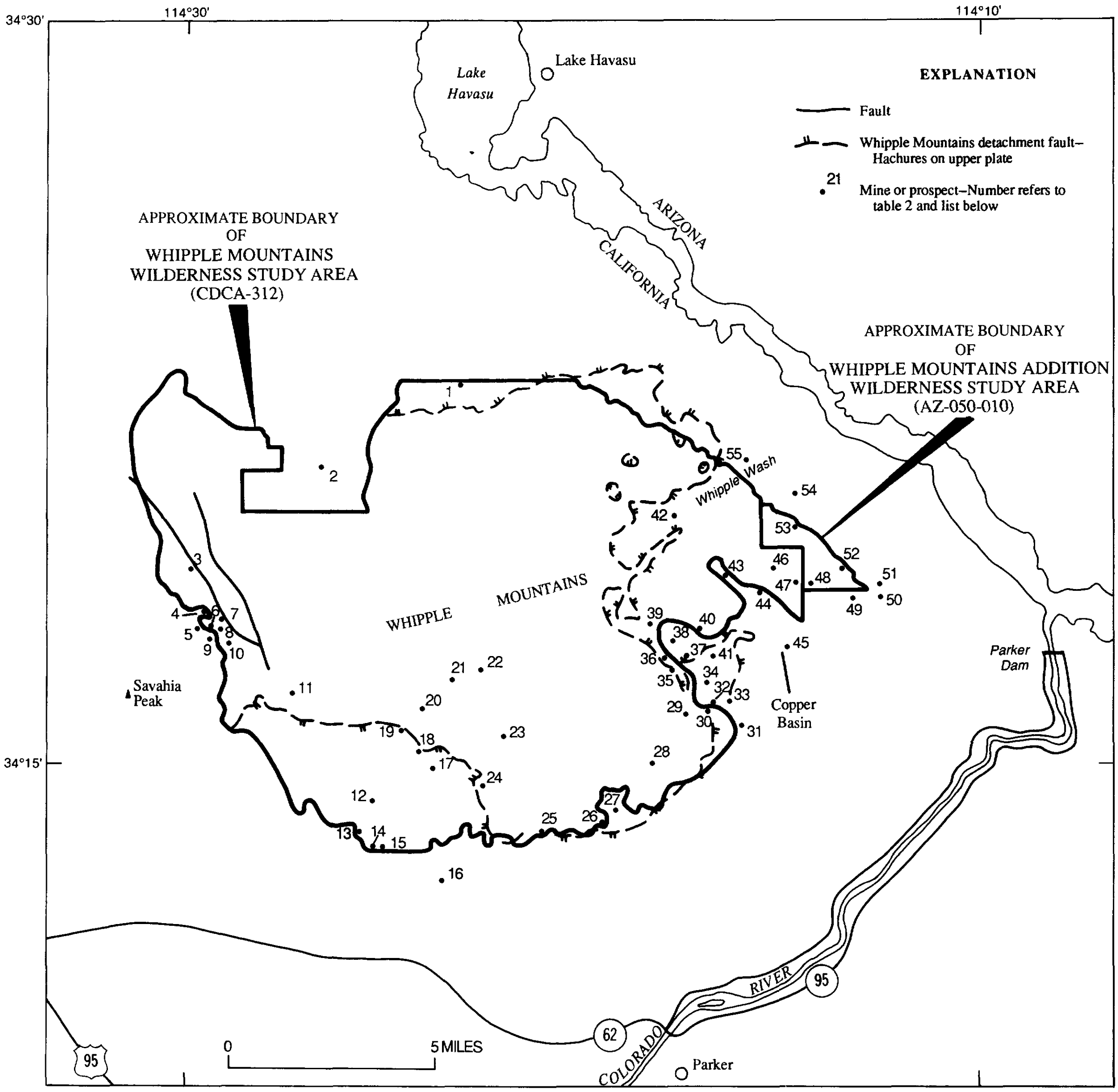
This mineral survey was requested by the U.S. Bureau of Land Management and is the result of a cooperative effort by the U.S. Geological Survey and the U.S. Bureau of Mines. An introduction to the wilderness review process, mineral survey methods, and agency responsibilities was provided by Beikman and others (1983). The U.S. Bureau of Mines evaluates identified resources at individual mines and known mineralized areas by collecting data on current and past mining activities and through field examination of mines, prospects, claims, and mineralized areas. Identified resources are classified according to a system that is a modification of that described by McKelvey (1972) and U.S. Bureau of Mines and U.S. Geological Survey (1980). Studies by the U.S. Geological Survey are designed to provide a scientific basis for assessing the potential for undiscovered mineral resources by determining geologic units and structures, possible environments of mineral deposition, presence of geochemical and geophysical anomalies, and applicable ore-deposit models. Goudarzi (1984) discussed mineral assessment methodology and terminology as they apply to these surveys. See appendixes for the definition of levels of mineral resource potential, certainty of assessment, and classification of identified resources.

Area Description

The Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas (fig. 1) encompass 86,480 acres in southwestern San Bernardino County, Calif. (U.S. Department of the Interior, Bureau of Land Management, 1980).

The study area is located on the east edge of the Mojave Desert 6 mi northwest of Parker, Ariz., and 10 mi south of Lake Havasu City, Ariz., and encompasses a major part of the Whipple Mountains. The borders of the study area are irregular and are defined by the Chemehuevi Indian Reservation and the powerline road on the north and northeast and by an unimproved dirt road on the west. The south and southeast border is approximately 1 mi north of the Colorado River aqueduct. Major access to the area is from California Highway 62 to the south and from a paved road on the west side of the Colorado River.

The local topography is dominated by the Whipple Mountains, which rise from 1,200 ft along the south border of the area to an elevation of 4,131 ft above sea level in the central part of the area. Several large northeast-trending canyons cut into the area from the north, the most scenic being Whipple Wash, which has vertical walls rising 500 ft from the canyon floor. The terrain is rugged with sloping flanks to the south and precipitous faces to the north.



MINES AND PROSPECTS

1. Stewart mine
2. War Eagle mine (old Roth, Virginia)
3. Sleepy Burro group (Whipple Mountain mine, Brainthruster mine)
4. New American Eagle mine
5. Prospect
6. Prospect
7. Prospect
8. Prospect
9. D & W mine
10. Atkinson group (patented)
11. Bluebird prospect
12. Dickie prospect
13. Turk Silver mine
14. Twin Lode mine
15. Decorative stone property (prospect)
16. Riverview mine (Tuscarora, Ethel Leona)
17. Prospect
18. Prospect
19. Double M No. 1 prospect
20. Lucky Green group (mine)
21. Thunderbird prospect
22. Black Mesas prospect
23. Lizard group (mine)
24. Golden Arrow group (prospect)
25. Prospect
26. Blackjack group (prospect)
27. Blue Cloud mine
28. Red Eagle group (Pasadena shaft, Horseshoe tunnel) (prospect)
29. Prospect
30 Prospect
31. Sunday Brass prospect
32. Prospect
33. Nickel Plate mine
34. Ruthie prospect (Homer claims)
35. Prospect
36. Van Horn mine
37. Monarch mine
38. Manganese King mine
39. Monument King mine
40. Prospect
41. Helen prospect
42. Prospect
43. Crescent mine (patented)
44. Venus prospect
45. Copper Basin mine
46. Copper Crest group (prospect)
47. Outpost claim (prospect)
48. Quadrangle Copper group (prospect)
49. Lortie group (prospect)
50. Peacock Copper group (prospect)
51. Gold Crown group (prospect)
52. Blue Heaven group (prospect)
53. Blue Heaven Extension (prospect)
54. Bonus group (prospect)
55. Klondike group (prospect)

Figure 3. Mines and prospects within and near the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas, San Bernardino County, California.

Previous and Present Investigations

Previous Studies

This report is a revision of Marsh and others (1982) and was written to assess additional acres within the Whipple Mountains Wilderness Study Area, assess the Whipple Mountains Addition Wilderness Study Area, bring the classification of undiscovered mineral resources up to date, and to compile information on the Whipple Mountains into one report. In addition to results from this investigation, further and detailed information can be found in many studies on the geology (Davis and others, 1980, 1982; Coney, 1980; Evans, 1979; Frost and Martin, 1982; Teel and Frost, 1982; Thurn, 1982), geochemical surveys (Erickson and others, 1987), remote sensing (G.L. Raines, unpub data, 1982), gravity and magnetics (R.W. Simpson, and T.B. Gage, unpub. data, 1982), geoelectrical surveys (D.B. Hoover, unpub. data, 1982) and an investigation of mines and prospects (Ridenour and others, 1982a, 1982b, 1987; Moyle and Gabby, 1985).

Investigations by the U.S. Bureau of Mines

The appraisal of identified mineral resources of the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas and vicinity was conducted in two parts (Ridenour and others, 1982a; Moyle and Gabby, 1985). The temporal and spatial relationships of mineral deposits and occurrences in the Whipple Mountains and vicinity are discussed by Ridenour and others (1982b). Preliminary work included a search of literature pertaining to geology and mineral resources within and near the study area; mining claim records were compiled from San Bernardino County and the U.S. Bureau of Land Management State office; and production records were compiled from U.S. Bureau of Mines files and California State publications. Attempts were made to contact all known claimants and owners of patented mining properties for permission to examine their prospects and mines and to obtain any scientific or historical information that would aid this study. All known mines and prospects were examined and sampled and, if warranted, mapped. Where possible, the limits of the mineralized rock were determined in order to establish tonnages for resource calculations. Resources, where estimated, are classified by levels of geologic assurance (measured, indicated, and inferred) and by likelihood for development (economic, marginally economic, and subeconomic).

Investigations by the U.S. Geological Survey

The U.S. Geological Survey, using geologic, geochemical, and geophysical techniques, investigated the study area to define the genesis of mineralization associated with mines and prospects, to determine if previously unknown mineral resources exist in the area, and to describe, wherever possible, the type and model for the mineralizing events. The defined areas of mineral resource potential (fig. 2) represent an evaluation as of 1981. C.M. Allen and K.A. Howard prepared the geologic base map from the many published geologic maps and reports on the Whipple Mountains. Sampling for a stream-sediment survey and rock sampling of selected mineralized areas were done in the spring of 1980 by S.P. Marsh and D.B. Smith. The geochemical data generated for this report were interpreted by S.P. Marsh. Aeromagnetic and gravity maps were prepared and interpreted by R.W. Simpson and geoelectric data were obtained and interpreted by D.B. Hoover. G.L. Raines interpreted remote-sensing data from LANDSAT images and ground observations.

Acknowledgments

Geologists of the U.S. Geological Survey, the U.S. Bureau of Mines, the University of Southern California, and San Diego State University contributed data and participated in discussions that were instrumental in defining the mineral resource potential of the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas. J.L. Anderson and G.A. Davis (University of Southern California), E.G. Frost (San Diego State University), and W.J. Carr (U.S. Geological Survey) provided valuable insights to the detailed geology and structural problems of the Whipple Mountains. J.K. Otton (U.S. Geological Survey) interpreted National Uranium Resource Evaluation (NURE) data in order to establish the uranium potential. Richard Knox (U.S. Geological Survey and U.S. Bureau of Land Management) participated in the many discussions on the mineral potential of the area.

APPRAISAL OF IDENTIFIED RESOURCES

By James Ridenour, Phillip R. Moyle, *and*
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U.S. Bureau of Mines

Methods of Evaluation

A total of 693 rock samples, 57 alluvium samples, and 31 petrographic samples were collected from the 55 sites examined in detail by the U.S. Bureau of Mines. Chip samples were collected from mineralized structures when possible, and grab samples were collected from dumps where underground workings were inaccessible; these samples were fire assayed for gold and silver. Quantitative amounts of visible or anomalous minerals or elements were determined by atomic-absorption, colorimetric, or X-ray fluorescence methods. At least one sample from each location was analyzed for 42 elements by semiquantitative spectrometry; elements in anomalous concentrations were then analyzed by one of the appropriate quantitative methods listed above. Petrographic examinations were performed to determine selected rock types, alteration suites, and mineral assemblages. Grab and channel samples of alluvium were collected from major drainages in the study area. These were panned to a rough concentrate and processed on a laboratory-size Wilfley table. Selected heavy-mineral fractions were analyzed for mineral content. Further information concerning analytical and other testing methodology, detection limits, and results is available in Ridenour and others (1987) and at the U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Ave., Spokane, WA 99202.

Mining History

Historic mining activity in the area was recorded by Root (1909), Bancroft (1911), and Jones (1920). Specific descriptions or notations of various mines, prospects, and mineralized areas in the region were given by Bailey (1902), Turner (1907), Aubury (1908), Graeff (1910), Stevens (1911), Wilson (1918), Cloudman and others (1919), Tucker (1921), Tucker and Sampson (1930, 1931, 1943), Noble (1931), Trask and others (1943), Eric (1948), Trask (1950), Wright and others (1953), Trengove (1960), and Fleury (1961). An overview of the mining in the California desert was written by Vredenburgh and others (1981).

Early claim records refer to the "Monumental" or "Whipple Mountains" mining districts within the region. The "Monumental" district probably encompassed Copper Basin, most of which lies outside the study area. The "Whipple Mountains" district includes mines and prospects in the vicinity of Savahia Peak, approximately 3 mi west of the study area. This area is referred to as the Chemehuevi district by Vredenburgh and others (1981) and is described as extending 20 to 50 mi inland (west) from the Colorado River. More than 5,000 claims were filed in and around the study area since the late 1800's; eight lode claims were patented. A search of the records did not reveal any placer claims in the vicinity of the study area. U.S. Bureau of Land Management claim recordations indicate approximately 165 active claims within the study area in February 1981.

U.S. Bureau of Mines files show 5,123 tons of ore were produced from 56 mines in what Clark (1970) refers to as the Whipple district, from 1906 to 1969 (exclusive of Copper Basin). The Copper Basin mine alone produced more than 40,000 lb of copper with some by-product gold and silver between 1930 and 1966 (U.S. Bureau of Mines files). Historic value of ore from the 56 mines is estimated at about $84,000; approximately 48 percent of the value is from gold and about 45 percent is from copper. About 2,500 long tons of manganese ore of unknown value was produced from five manganese mines from World War I to the 1950's in response to Government stockpiling programs.

Many of the historic mine names in the Whipple district could not be equated to modern names found in the claim records. Therefore, production from many mines within the study area is undetermined.

Appraisal of Sites Examined in the Whipple Mountains Wilderness Study Area

Mines and prospects with identified resources are listed in table 1; summary descriptions of the 55 properties examined are given in table 2.

None of the properties with identified resources appear to be economically minable at the average 1986 prices of gold, silver, copper, and manganese. In terms of likelihood for development, the Copper Basin mine just outside the study area is the most important property. Although this area was extensively explored by industry, there were no known plans in 1983 to develop the deposit. This may be due to its small size in comparison to copper deposits of south-central Arizona, some of which are at least 10 times larger in terms of contained resources.

The highest grade deposit, immediately adjacent to the study area, is the Crescent mine (pl. 1, fig. 3 and tables 1 and 2, No. 43). The 17,000-ton resource is estimated to contain 0.14 oz/t gold, valued at approximately $59/t (gold = $424/oz), and 2.4 percent copper, valued at $36/t (copper = $0.77/lb), for a total unit value of $96. Such a flat-lying deposit would best be mined by the room-and-pillar method, which would require at least a 4.0-ft mining width and have a 10 to 15 percent loss in pillars; therefore, the unit value would be diluted to approximately $67/t. Because of the high copper content, gold recovery may be as low as 50 percent, further reducing the value to about $46/t. For evaluation purposes (Clement and others, 1979), the mine should have at least a 5-yr life or a minimum of about 100,000 tons for a production rate in the range of 50 to 100 t/d for 250 d/yr. The costs to mine the deposit include a $7.50/t mine capital cost and a $24/t mine operating cost. The least expensive and most effective recovery method, heap leaching (including crushing facilities), would require a minimum $1.5 million capital cost ($65/t) and would cost approximately $15 to $20/t to operate. Alternatively, the material could be treated at the nearest custom mill at Vanderbilt, Calif., 150 mi to the northwest. Haulage would cost approximately $18 to $20/t, and milling would cost about $25 to $30/t. Therefore, the resources at the Crescent mine are subeconomic at the commodity prices specified.

Despite the economics of mining at the average 1986 prices of copper and gold, available data at four other copper-gold properties are sufficiently encouraging to indicate further investigation. These are the War Eagle mine (outside study area) and the Sleepy Burro group, New American Eagle mine, and the Copper Crest group within the study area (pl. 1, fig. 3, and tables 1 and 2, Nos. 2, 3, 4, and 46). All of these properties are located on or near large faults or fault systems that provided major avenues for movement of hydrothermal solutions. Although the War Eagle, New American Eagle, and Sleepy Burro underground workings were inaccessible at the time of the study, descriptions of the properties by earlier investigators and recent induced polarization (IP) surveys (Marsh and others, 1982) suggest the presence of possibly minable resources. Evaluation of the IP anomalies through drilling would be the most feasible and least costly means to test for resources. The Copper Crest group, in upper plate rocks, was not explored to the extent of the other three workings, but copper and silver content of selected samples indicate further investigation is warranted.

Selective mining of manganese outcrops and stoping of underground pods at the Monarch, Manganese King, and Monument King mines (pl. 1, fig. 3, and table 2, Nos. 37, 38, and 39) could yield small quantities of manganese. The mining would be labor intensive, and the grade would only be 20 to 30 percent manganese. Because the deposits are classified as ferruginous manganese containing 10 to 35 percent manganese, additional milling would be necessary to upgrade the resources. Manganese ore (minimum 48 percent manganese with low impurities) sold at United States ports for $1.35 to $1.40/long ton unit (Engineering and Mining Journal, Mar. 1987, p. 19). Transportation costs to major consumers in the eastern United States were prohibitively high in 1986. If the Federal Government institutes a manganese purchase program to build stockpiles of this strategic metal, further exploration of these mines would be warranted. Drilling may reveal additional manganese pods and lenses at depth similar to grades of 25 to 50 percent manganese produced in the past.

Certain factors could affect the economics of mineral deposits in the study area and vicinity. For example, technological advancements that would decrease mining or milling costs or increase milling recovery, such as improving gold recovery from copper-gold resources at the Crescent mine, could result in upgrading the resource classification to economic. Development of a nearby mine and mill, such as at Copper Basin, could provide a cost effective mill for small deposits in and near the study area. Finally, significant increases in commodity prices whether or not accompanied by a concomitant increase in the demand for the raw materials, could lead to further interest in exploration within the study area.

Voluminous occurrences of common borrow, sand, and gravel are in Quaternary alluvium in canyons and drainages radiating from the core of the study area; however, most of these occurrences are outside of the study area at lower elevations. Thirteen of 56 samples of alluvium collected from these occurrences contain no gold. The gold value in six of the samples was from $.05 to $1.37/yd^3 at a price of $424/oz; in the remaining samples it was from $.01 to $.03/yd^3. Thus, the gold is not in sufficient quantity to constitute resources or improve the economics of extracting the alluvium for other purposes. Because of the high-bulk low unit value of the alluvium and the high transportation costs involved in shipping to distant markets, development is unlikely in the foreseeable future other than for local uses. These same influences of market outlets (demand), low unit value, and high transportation costs also affect the minability of identified decorative stone within the study area.

Appraisal of Sites Examined in the Whipple Mountains Addition Wilderness Study Area

Forty-six samples collected from six sites within and immediately adjacent to the Whipple Mountains Addition Wilderness Study Area contain gold that ranges from a trace to 1.56 oz/t; most samples contain less than 0.1 oz/t. Because the workings at most of these sites were unsafe to enter and the structures exposed by them discontinuous, no resources were identified. However, at most sites the structures are numerous and the gold is apparently not confined to a particular set of fractures. Finally, the workings are all in upper plate rocks and have been subjected to intense ground preparation. In view of the substantial increase in gold mining in the western states during the past ten years, these factors suggest that the sites warrant further investigation, which could lead to identified resources.

Voluminous occurrences of common borrow, sand, and gravel are in Quaternary alluvium in canyons and drainages in and near the Whipple Mountains Addition Wilderness Study Area; however, most of these occurrences are outside of the study area at lower elevations. Because of the high bulk-low unit value of the alluvium and the high transportation costs involved in shipping to distant markets, development is unlikely in the foreseeable future other than for local uses.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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Geology and Structure

The Whipple Mountains form one of more than 25 distinctive metamorphic terranes in the North American Cordillera that have been referred to as "metamorphic core complexes" (Coney, 1980; Crittenden and others, 1980).

These terranes are characterized by metamorphic-plutonic basement rocks overprinted by low-dipping mylonitic fabrics and overlain on decollements (detachment faults) by a fault-sliced and attenuated unmetamorphosed cover (Coney, 1980). The Whipple Mountains typify this description. Numerous recent studies have investigated the geology of the Whipple Mountains (Anderson and others, 1979; Carr and others, 1980; Dickey and others, 1980; Frost, 1980; Davis and others, 1980, 1982; Anderson and Rowley, 1981; Carr, 1981; Anderson, 1981). These studies show that the structure of the Whipple Mountains is dominated by a low-angle detachment fault of Tertiary age, which juxtaposes two unlike assemblages of rocks. This fault, the Whipple Mountains detachment fault, separates a footwall or lower plate exposed in the domal core of the range from an upper plate exposed around the flanks.

The lower plate below the fault is comprised largely of Proterozoic metamorphic and plutonic rocks. Below and east of a mylonite front exposed in the western part of the study area and mapped as the contact between mylonitic rocks (mr) and gneiss (gnd) (pl. 1 and fig. 1), the Proterozoic rocks have a gently dipping mylonitic foliation associated with Cretaceous and Tertiary granitic sheet intrusions (Davis and others, 1982; Wright and others, 1976). Petrologic studies suggest that the granitic sheets were emplaced at depths exceeding 6 mi (Anderson and Rowley, 1981; Anderson, 1981). Regionally, deep-seated rocks such as these are generally barren of sulfide mineralization except where affected by younger events. Lower plate crystalline rocks above the mylonite front are intruded by Tertiary dikes of diabase to dacite composition in the dense Chambers Well dike swarm (Davis and others, 1982; Carr and others, 1980).

The upper plate is composed of crystalline rocks overlain by Tertiary volcanic and sedimentary strata (Davis and others, 1980, 1982). Proterozoic igneous and metamorphic rocks forming most of the crystalline assemblage are intruded by one or more Cretaceous granite plutons. A mineralization halo in Proterozoic rocks at Copper Basin, a mile east of the study area, has been related to intrusion of nearby Cretaceous granite by Anderson and Frost (1981) on the basis of like potassium-argon ages of the granite and the altered rocks. Metallic mineralization is common in similar rock assemblages in other parts of southeastern California and Arizona. The upper-plate Tertiary volcanic rocks are andesite, basalt, and tuff, which are typically altered and secondarily enriched in potassium. Interbedded sedimentary rocks are conglomerate, sandstone, and lacustrine shale and limestone. The upper plate is overlain unconformably by fanglomerate and basalt of Miocene age, estuarine clay, silt, sand, and marl of Miocene and Pliocene age (Bouse Formation), and alluvial and fluvial deposits of Quaternary age (Dickey and others, 1980; Davis and others, 1980; Carr, 1981).

Regional relations demonstrate that a sequence of Paleozoic and Mesozoic strata similar to those now exposed in northwestern Arizona was once deposited across the area (Hamilton, 1982). These rocks were mostly eroded before middle Tertiary time, probably as a result of Mesozoic deformation and uplift. Mesozoic deformation is recorded not only by mylonites and granitic sheets in the Whipple Mountains lower plate, but also by folds, thrust faults, and metamorphism in areas to the south (Hamilton, 1982; Carr and Dickey, 1980), west (Miller and others, 1982), and east (Reynolds and others, 1980). The Whipple Mountains detachment fault commonly crops out as a ledge of impermeable microbreccia, below which is a zone of alteration, faulting, and brecciation termed the chlorite breccia zone, which is as thick as 400 ft. Contained within this structurally disturbed zone are brecciated clasts with a matrix of chlorite, epidote, silica, and sulfide minerals, especially pyrite; the alteration and mineralization render the zone hard and relatively impermeable (Frost, 1980; E.G. Frost, written commun., 1982). Fracturing and alteration are typically most intense where the lower plate rocks are mylonitic (Davis and others, 1982). E.G. Frost (written commun., 1982) suggested that ore minerals may have been leached from the areas of most intense fracturing and alteration and that nearby sites, particularly in upper-plate crystalline rocks, may have been favorable for redeposition of ore minerals. Detachment faults below the main detachment surface in places mark the base of the chlorite breccia zone (Frost, 1980; Davis and others, 1982). Above the Whipple Mountains detachment fault, the upper plate is cut by a series of northeast-dipping normal faults that repeat over and over again the Tertiary section and underlying upper plate crystalline rocks (Davis and others, 1980; Frost, 1980; Dickey and others, 1980). These faults join or bottom against the detachment fault. The upper plate blocks are rotated to southwest dips along these faults and are locally crushed or broken by antithetic faults as a result of the rotation (Frost, 1980). The oldest Tertiary beds dip more steeply than younger ones, suggesting that detachment and related normal faulting took place during deposition of strata (Frost, 1979; Davis and others, 1980). Much of the mineralization of the area, including redistribution of ore minerals at Copper Basin, occurs in the upper plate and can be related to the Miocene structural disruption and associated hydrothermal alteration (Wilkins and Heidrick, 1982; Ridenour and others, 1982a). The detachment fault defines gentle troughs and ridges that Frost (written commun., 1982) and Wilkins and Heidrick (1982) have suggested may partly control sites of ore deposition. Cameron and Frost (1981) interpreted these troughs and ridges as folds. Carr (1981) suggested that horizontal offset along the Whipple Mountains detachment fault probably exceeds 12 mi. Studies in nearby areas suggest that the detachment fault has considerable vertical offset, as well as unknown horizontal offset, and juxtaposes rocks that were originally at different levels in the crust (Hamilton, 1982; Howard and others, 1982). The lower plate assemblage of rocks in the western part of the study area resembles upper plate rocks 20–25 mi to the northeast in the Mohave Mountains and may be their beheaded equivalent (G.A. Davis, oral commun., 1979; Howard and others, 1982). The rocks in the Mohave Mountains are extensively mineralized (Light and others, 1982). These relations raise the possibility that the western part of the Whipple Mountains contains deeper parts of the mineralized system(s) that affected the Mohave Mountains. Thick tilted upper plate blocks in the Mohave Mountains area suggest that the Whipple Mountains fault and its footwall originally lay at depths of several miles, perhaps 7.5 mi or more (Howard and others, 1982). Tectonic denudation and large uplift apparently have since exposed the fault and lower plate. Locally mineralized faults with postdetachment fault movement occur in the western part of the study area (Dickey and others, 1980; Carr and others, 1980). Virtually undeformed and unmineralized rocks deposited unconformably across the deformed terrain demonstrate that most deformation had ended by 13 million years ago (Dicky and others, 1980; Davis and others, 1980; and Carr, 1981).

Geochemistry

Sample Media and Analytical Methods

A reconnaissance geochemical study to assess the mineral resource potential of the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas was undertaken in 1980. Three sample media were selected as best representing this area in the arid desert environment of southeastern California: stream sediments, panned concentrates, and rocks. Sediments and concentrates were collected from 154 drainages in the study area, each drainage representing a 1–2 mi^2 area. Selected samples were collected from areas of altered outcrops and from existing mining areas to determine mineral suites and trace-element signatures of mineralized systems. The samples were processed, and the minus-80-mesh fraction of sediment and the nonmagnetic heavy (greater than 2.86 specific gravity) fraction of concentrate were analyzed for 31 elements by the semiquantitative-emission spectrographic method (Grimes and Marranzino, 1968). Rock samples were pulverized and also analyzed by a semiquantitative-emission spectrographic method. Data from these analyses for the study area are listed in Erickson and others (1987). Semiquantitative spectrographic analyses of the nonmagnetic fraction of the panned concentrates proved to be the most useful in evaluating the study area. This sample medium contains the common ore-forming sulfide and oxide minerals as well as barite and other nonmagnetic minerals (zircon, apatite, fluorite, rutile, and some sphene). The concentrate medium also gives a greatly enhanced anomaly pattern, as all of the more common (low specific gravity, less than 2.86) rock-forming minerals (quartz and feldspar) that tend to dilute the anomalies have been removed. To investigate the relation of limonite occurrences to hydrothermal alteration related to mineralization, the intermediate magnetic fraction of the panned concentrates was analyzed. This sample medium was used because it contain the adsorbed iron and manganese oxides on sediments from the representative drainage basins. The iron and manganese oxides were dissolved from the samples using hot aqua regia and were analyzed using the induction-coupled plasma spectrograph (ICP) (Church, 1981; and Church and others, 1982) to see if they contain anomalous concentrations of metals.

Results of Study

The regional geochemical survey in the Whipple Mountains Study Area delineated regions of mineralization, helped identify areas of hydrothermal alteration and helped establish the relation of mineralization to the Whipple Mountains detachment fault. In addition, the survey identified geochemical suites of elements characterizing the rocks in the Whipple Mountains.

Geophysics

Geophysical investigations were conducted by the U.S. Geological Survey as part of the multidisciplinary study of the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas. The work included aeromagnetic, gravity, IP, and remote-sensing studies, vertical electrical soundings, and audiomagnetotelluric readings.

Aeromagnetics and Gravity

Regional aeromagnetic and Bouguer gravity maps both display large positive anomalies in the western part of the study area (R.W. Simpson and T.B. Gage, unpub. data, 1982; U.S. Geological Survey, 1981; Chapman and Rietman, 1978). The very highest total-field magnetic values occur about 1 mi south-southeast of the War Eagle mine (pl. 1, fig. 3, and table 2, No. 2) over a small gabbro outcrop. An arm of the magnetic high extends to the north-northeast where it coincides with outcrops of mafic diorites (G.A. Davis, oral commun., 1982). The coincidence of the broad magnetic and gravity highs requires a source body that is both magnetic and dense, such as gabbro or the Tertiary diorite. The extent of the anomalies suggests occurrence of considerably more of these mafic materials at depth than are seen at the surface. To the west, the major aeromagnetic high joins the north end of a linear north-northwest-trending aeromagnetic high, which parallels the axis of the Chambers Well dike swarm (G.A. Davis, oral commun., 1982). A lower high-amplitude high area continues farther to the west and generally matches the westward broader extent of the dike swarm. The steepest gradient on the west side of the linear north-northwest-trending central anomaly passes near the New American Eagle and D & W mines (pl. 1, fig. 3, and tables 1 and 2, Nos. 4 and 9) and may mark a structure that has permitted movement of mineralizing solutions. This possibility is strengthened by the presence of coincident linear gravity gradients trending north-northwest that have been inferred by Healey and Currey (1980) to mark a through-going fault. Mapped faults parallel to this trend also appear nearby (Stone and Howard, 1979). On the north edge of the study area, there are fewer mines and prospects than occur on the west. As previously mentioned, the War Eagle mine lies just north of the highest part of the magnetic high, perhaps indicating the boundary of a mafic body. The north-northeast-trending linear gradient that bounds this high on the northwest (about 0.6 mi south-southeast of the War Eagle mine) is again suggestive of structural control, as is a more diffuse north-northwest-trending magnetic gradient that passes through the location of the War Eagle mine.

Geoelectrics

Within the study area, four IP survey lines were run in the vicinity of the D & W and New American Eagle mines (pl. 1, fig. 3, and tables 1 and 2, Nos. 9 and 4) and two in the vicinity of the War Eagle mine (pl. 1, fig. 3, and table 2, No. 2). These lines were run because the IP method provides a direct indication of polarizable minerals such as clays and sulfides with metallic luster and thus can provide evidence for the possible extent of mineralization at depth in the vicinity of the mines. In addition to the IP surveys, twelve Schlumberger vertical-electrical soundings (VES) and three experimental audio-magnetotelluric (AMT) soundings were made. The VES were made to determine variations in resistivity with depth at selected sites within the core complex and in nearby upper plate rocks.

In the vicinity of the New American Eagle and D & W mines, IP work showed a southeast-trending polarizable zone at least 5,000 ft long passing directly through the New American Eagle mine. The observed ability for polarization is low but distinctly above background levels. The polarizable zone is believed to be a direct expression of the mineralized body mined at the New American Eagle. IP data indicate that the body extends at least 980 ft in depth. Where identified by the IP lines, the zone is entirely within the study area and probably continues within the area for some distance. One line crossed the D & W mine, but no polarizable body was observed near the mine. The main polarizable structure is located about 1,900 ft northeast of the D & W shaft. The apparent lack of a polarizing body at the D & W mine could either represent leakage of mineralizing fluids along a structure or could indicate an altered body at depth.

At the War Eagle mine the IP data show a polarizable body similar to that observed at the New American Eagle mine. Values for the ability for polarization were slightly larger than observed near the New American Eagle mine and were the largest observed in the study area. The data suggest a broad (320-ft-wide) near-vertical zone of increased polarization extending to at least 1,000-ft depth near the War Eagle shaft. Because only one IP line crossed the structure, the trend and lateral extent are unknown. The data also suggest that a broad zone of slightly increased fracturing or alteration may extend south of the War Eagle mine, with increased polarizability at depth. One IP line crossed the inferred trace of the detachment fault north of the War Eagle mine. The fault was clearly identified in the data as an abrupt resistivity interface dipping north. Resistivities ranged from moderate values (100–200 ohm-meters) associated with the lower plate rocks to low values associated with the upper plate rocks in this area. No polarization anomaly was associated with the detachment fault here, indicating a lack of sulfide mineralization or polarizable clays in the fault zone. In the Whipple Mountains, mineralization generally associated with the detachment fault extends only short distances into the lower plate rocks. There is no IP response associated with the detachment fault near the War Eagle mine, and yet a clear IP response at the War Eagle mine to some depth suggests mineralization well within the lower plate here. It appears that further work is needed before an understanding of the source of mineralization is achieved. Vertical electrical soundings within the lower plate showed near-surface resistivities of about 100 ohm-meters slowly increasing to about 1,000 ohm-meters at depth. This is interpreted to represent a normal reduction of porosity with depth due to overburden pressure. A line of six soundings crossed the detachment fault north of the War Eagle mine and also clearly showed the presence of the fault. The data give a minimum apparent dip of 20 on the detachment surface.

Remote Sensing

As a part of this study, limonitic materials were identified in LANDSAT images of the Whipple Mountains and surrounding areas using a color-ratio-composite method (Rowan and others, 1974). This technique was used to map areas of hydrothermal alteration associated with limonitic materials and to help define potential mineralized systems. The term limonite is used as a general term for hydrous iron oxides (Blanchard, 1968) but is modified to include any material with the unique spectral reflectance properties of the ferric oxide minerals such as hematite and goethite

(Hunt, 1980). The minerals pyrite and (or) hematite are commonly associated with hydrothermal alteration that is potentially related to mineralization; these minerals weather to produce limonite, which is detected by this technique. Areas of hydrothermal alteration that lack limonitic materials will not be detected by this technique; however, areas of this type, without limonite, are insignificant within the study area. All areas within the study area defined as limonitic from the satellite analysis were visited and sampled selectively to determine if the limonite was associated with hydrothermal alteration and, if so, with what type of alteration and (or) mineralization (pl. 1). The selected rock samples from limonitic areas were analyzed by a semiquantitative-emission spectrographic method (Grimes and Marranzino, 1968) to determine trace-element assemblages associated with mineralization, in order to help define the type and extent of any mineralizing process that could have produced the observed hydrothermal alteration. From these hydrothermal-alteration studies, several mineralized areas were identified, and the extent, distribution, and type of alteration were mapped.

Mineral and Energy Resource Potential of the Whipple Mountain Wilderness Study Area

Within the Whipple Mountains Wilderness Study Area, most of the mines and prospects and many of the limonitic areas of hydrothermal alteration are spatially related to the low-angle Whipple Mountains detachment fault. Most of the mineralization observed is in the upper plate and, although seen in places in lower plate rocks, rarely extends very far below the fault zone. Mineralization related to the fault zone is primarily copper, lead, zinc, gold, and silver with the elemental suite copper-silver-gold predominating. Varying amounts of lead and zinc are also present. The mineralization is also seen in veins and fractures related to listric and antithetic faults (Ridenour and others, 1982a, 1982b) resulting from dislocation of upper plate rocks. The observed minerals are oxides and carbonates with rare sulfides. Along the southeast margin of the area, in upper plate rocks, one or several Cretaceous granite bodies have been dislocated by northwest-striking normal faults that repeat much of the upper plate section (Dickey and others, 1980). Concentrations of copper, lead, zinc, gold, and silver minerals are spatially related to these granitic bodies, are also dislocated by the northwest-trending faults, and are apparently genetically related to intrusion of the granite. Tertiary volcanic rocks are limited to the upper plate of the Whipple Mountains detachment fault and contain small manganese deposits and prospects. The manganese occurs as psilomelane and pyrolusite in irregular masses in areas of solfataric alteration accompanied by silicification.

Barite veins are common throughout the upper plate and also occur in the lower plate. Barite is a common secondary mineral in all the vein systems throughout the area in both upper and lower plate rocks. Tertiary lake bed sediments in the eastern part of the wilderness study area contain anomalous concentrations of uranium, and decorative sandy limestone was exploited at a small rock quarry near the south boundary.

Mineralization Related to the Whipple Mountains Detachment Fault—Copper, Lead, Zinc, Gold, and Silver

The most visible mineralization in the Whipple Mountains is the ubiquitous, structurally controlled occurrence of chrysocolla (copper silicate) related to the Whipple Mountains detachment fault. The chrysocolla occurs in rocks from lower plate mylonitic and nonmylonitic assemblages to the upper plate Tertiary section. It occurs as thin coatings to massive, podiform to lensoid bodies as much as a few inches thick. Lateral extent of the chrysocolla occurrences is commonly limited to a few inches, but several such occurrences can be expected along the strike length of any given fracture system. The chrysocolla is usually accompanied by earthy hematite, quartz, specular hematite, limonite, calcite, barite, chlorite, epidote, and sericite. Barite and calcite associated with the chrysocolla are more prevalent in upper plate rocks. The type of alteration associated with the deposits is a chlorite-dominated propylitic assemblage, although quartz-sericite alteration was also observed. Spotty, low-grade, gold and silver are associated with the chrysocolla-hematite assemblage (Ridenour and others, 1987).

Immediately below the detachment fault lies an altered and highly disturbed zone called the "chlorite breccia zone 1" (Frost, 1980). Chlorite tends to be concentrated in and near this zone and appears to diminish in overall content upward. Pyrite and chalcopyrite as disseminated in the chlorite breccia zone. Disseminated pyrite and chalcopyrite have been reported in drill logs in the upper plate crystalline suite at Copper Basin, just east of the study area boundary (Ridenour and others, 1987). The probable minimum age for the mineral occurrences associated with upper plate fractures that resulted from detachment faulting is middle Miocene, and the probable maximum age is late Oligocene, as suggested by a 24.5 0.7 million year (Ma) potassium-argon age of sericite determined by R.F. Marvin (written commun., 1982). Collectively, field observations and age data indicate a contemporaneous relation between mineralization and detachment in the study area (Ridenour and others, 1982b).

Structural analyses of fractures in mineralized areas above and below the detachment fault indicate crustal lengthening in the lower plate and dislocation in the upper plate. A total of 286 observations of attitudes of mineralized structures were separated into lower and upper plate populations and analyzed by computer. A concentration of attitudes in the lower plate were oriented N. 26° W., and dipped 48° NE. Attitudes in the upper plate structures show a dominant cluster at N. 45° W., 28° NE., and a secondary cluster centered about N. 46° W., 66° SW. Upper plate data suggest probable structural control by northeast-dipping listric and normal faults and southwest-dipping antithetic and bedding-plane faults. The pattern of tension fractures in the lower plate is compatible with a N. 50°±10° E. direction of crustal extension, which is also the inferred direction of movement of the upper plate (Ridenour and others, 1982b).

The upper plate of the Whipple Mountains detachment fault is lithologically varied and contains Proterozoic and Mesozoic crystalline rocks and Tertiary volcanic and sedimentary rocks that have undergone severe structural disruption during the period of detachment faulting (Davis and others, 1980, 1982). Mineralization occurred in this disturbed upper plate in normal faults, shear zones, and tension gashes.

Two areas in orassociated with the Whipple Mountains detachment fault have high potential for copper, lead, zinc, gold, and silver resources (pl. 1, fig. 2): (1) a large area in the south-southwest part of the wilderness study area and (2) a smaller area on the west side of the study area.

Analyses of stream sediments and panned concentrates in these two areas revealed that the southern area was more heavily mineralized than the western area. The boundaries of the southern area extend somewhat beyond the outcrop pattern of upper plate rocks to include some mines and prospects in the chlorite breccia zone that occur at or very near the detachment fault zone and are related to upper plate mineralization. The semiquantitative spectrographic analyses of nonmagnetic panned concentrates show a trace-element suite related to copper, lead, zinc, gold, and silver mineralization. This suite consists of copper greater than or equal to 100 parts per million (ppm) and lead greater than or equal to 200 ppm, with varying amounts of molybdenum (10–50 ppm) and silver (3 ppm). Barium is ubiquitous; most samples contain more than 0.5 percent and reflect the many barite veins seen in the field. The copper-lead anomalies are strongest from areas that drain known mineralized areas, but all samples from both areas of high resource potential show a similar suite of anomalous metal concentrations.

Several areas of limonitic material were defined in the southern area (propylitic alteration, pl. 1) by remote sensing, and visits to these zones revealed that they are areas of propylitic alteration and structural complexity and are mainly sites of previous mining activity. The intermediate magnetic fraction of panned concentrates from streams draining these areas was analyzed by ICP, and the results reveal that along with anomalies in copper, lead, and zinc, anomalies in arsenic that range from 30 to over 400 ppm are also present. Spectrographic analyses of rock samples from the Blue Bird prospect in a propylitic (limonitic) zone (pl. 1, fig. 3, table 2, No. 11) identified anomalies in copper (1,000 ppm), lead (as much as 2 percent), zinc (as much as 1 percent), silver (5–20 ppm), molybdenum (15–20 ppm), arsenic (as much as 1 percent), and bismuth (300 ppm). The area around the Blue Bird prospect is the most highly mineralized zone in the study area. Observed mineral assemblages and structural history suggest that mineralization was epithermal and related to middle Tertiary volcanism and structural disruption. Remobilization of metals for a few tens of feet along structures into the otherwise barren lower plate probably occurred at the time of detachment faulting.

Two other highly mineralized areas are present within the southern area and were studied in some detail during this investigation. They are at the Turk Silver mine (pl. 1, fig. 3, and tables 1 and 2, No. 13) and the Lucky Green group of claims (pl. 1, fig. 3, and tables 1 and 2, No. 20). The Turk Silver mine lies just inside the south border of the study area in a large area of propylitic (limonitic) alteration in Tertiary volcanic rocks. The mine consists of three shafts and two adits in a fault breccia zone between sedimentary and volcanic rocks. Eight rock samples were collected from exposed veins, faults, and shear zones, and one soil sample was collected in the vicinity of the mine workings. They were analyzed by semiquantitative spectrographic methods and yielded high values for copper, lead, and zinc: as much as 2,000 ppm silver was recorded from one black calcite vein. High cadmium values (as much as 150 ppm) associated with high zinc values indicate that these are lower temperature veins, probably distant from the source rocks (Levinson, 1980). Barite veins are common and corroborate the finding of high barium (500 to greater than 5,000 ppm) in the rock samples. The soil sample collected near the mine also contains copper, lead, zinc, and silver. W.J. Carr (written commun., 1982) suggested the Turk mine is on the same fault zone that in the area to the northwest (pl. 1 and fig. 2) is associated with mineralized rocks in the lower plate.

The Lucky Green group lies in the chlorite breccia zone below but very near the Whipple Mountain detachment fault. Mining activity in the Lucky Green group consists of four large open cuts, several smaller cuts, two short adits, and numerous drill holes in the lower plate. The Lucky Green group lies in the chlorite breccia zone. The mineralization is in gneiss that has been intruded by granite. Although no identified pervasive alteration zone was observed, quartz-sericite-chlorite alteration was seen locally on fractures. Two rock samples from the mineralized area were analyzed by semiquantitative spectrographic method. All of the elements related to copper, lead, zinc, gold, and silver mineralization are present in detectable amounts, but copper is the most abundant (greater than 2 percent).

The smaller area of high resource potential is on the west side of the study area, but metal concentration is much lower and the low relief of the topography made obtaining representative stream-sediment samples difficult. The entire area was identified from LANDSAT images as a limonitic zone. Field observations identified propylitic alteration and barite veins; rock samples collected at a prospect pit in the zone contains copper (1,000 ppm), lead (as much as 2 percent), zinc (as much as 1 percent), silver (150 ppm), and arsenic (greater than 1 percent). High cadmium values (300 ppm) paired with greater than 1 percent zinc values indicate that mineralization was epithermal (Goldschmidt, 1954).

Mineralized zones in the western area of high resource potential are associated with faults that strike northwest and that may be part of a postulated regional northwest-trending fault zone defined by a gravity gradient to the north and south of the study area (Healy and Currey, 1980). Mineralized rocks are also apparently associated with the north-northwest-trending hypabyssal dike swarm that intrudes the lower plate rocks but is truncated by the detachment fault. The structural relations in this area indicate that the mineralization occurrs high in the lower plate relatively close to the detachment surface and is possibly associated with displacement within the northwest-trending fault zone along which upper plate rocks were locally mineralized.

Criteria used to assess the mineral resource potential in these two areas (pl. 1, fig. 2) are (1) geologic terrain favorable for mineral deposits consisting of highly faulted host rocks, (2) anomalously high amounts, in various sample media, of copper, lead, and zinc with lesser, though still anomalously high, amounts of gold, silver, arsenic, and molybdenum, (3) presence of several old mines with possible production and numerous prospects, and (4) areas of propylitic alteration and barite veining. The two areas are considered to have a high mineral resource potential for copper, lead, zinc, gold, and silver with a certainty level of C.

The aforementioned discussion primarily addresses the upper plate rocks. The lower plate of the Whipple Mountains detachment fault, however, is also lithologically varied and contains Proterozoic to Mesozoic and lower Cenozoic igneous and metamorphic rocks and their deeper, mylonitic equivalents according to Davis and others (1980, 1982). The lower plate, except as noted above, is mostly barren; where mineralized rock is found, it rarely extends to any great depth. Most mineralized rock observed in the lower plate is in the chlorite breccia zone and is therefore apparently related to the detachment fault. In the lower plate, mineralized rock seen along the west, north, and east borders of the study area appears to be related to other features such as dike swarms, postdetachment faults, and gravity and aeromagnetic anomalies.

An area of moderate resource potential for copper, lead, zinc, gold, and silver lies on the west edge of the wilderness study area, between the two areas of high resource potential for the same metals (pl. 1 and fig. 2). In this area of moderate potential, the mineralizing processes that took place in the western high potential area seem weaker but were active in this zone to a lesser extent. The mineralizing processes consist of association with northwest-trending fault zones defined by a gravity gradient, association with north-northwest-trending hypabyssal dikes, and position in the lower plate in assumed close proximity to the upper plate. Geochemical anomalies in the stream sediments and panned concentrates from this area are sparse, owing partly to the low relief and partly to the localization of mineralization in the northwest-trending fault zones, away from stream drainages. Samples of sediment and concentrate collected from drainages cutting the mineralized fault zones contain high values for copper and barium and varying amounts of lead (100–300 ppm), silver (as much as 3 ppm), molybdenum (10–15 ppm), and tungsten (200–500 ppm). This elemental suite is slightly different from that seen in the upper plate (presence of tungsten, absence of zinc), possibly because it is more closely related to primary sulfides than to the secondary carbonates and oxides. No pervasive altered (limonitic) zones were identified in the area, and ICP analyses from the leach of the intermediate magnetic fraction of the panned concentrates reflect this lack of iron and manganese oxides. The ICP analyses revealed only scattered low concentrations of molybdenum and one high copper anomaly, which come from a stream draining one of the mining areas.

A highly mineralized area around the New American Eagle mine (pl. 1, fig. 3, and tables 1 and 2, No. 4), within the area of moderate mineral resource potential, was studied in detail during this investigation. This mine lies on the northwest-trending fault zones and is in gneiss that has been intruded by the predetachment hypabyssal dike swarm. This mine consists of two shafts and several pits and cuts. Five rock samples were collected from an outcrop at the mine for trace-element geochemistry and were analyzed by a semiquantitative spectrographic method. In addition, one of the samples was analyzed for gold, tungsten, antimony, arsenic, and mercury by atomic-absorption methods (Ward and others, 1959; Welsch and Chao, 1975; Meier, 1980; and Leinz and Grimes, 1978) to see if this area of mineralization contains a gold suite of elements suggestive of epithermal precious-metal vein systems. In this rock sample, gold (12 ppm) and arsenic (20 ppm) are the only elements present in anomalous concentrations, and the existence of an epithermal precious-metal vein system seems unlikely. Spectrographic results of the five rock samples show anomalous amounts of copper (as much as 2 percent) and silver (as much as 300 ppm) with lesser, but still anomalous amounts of bismuth, molybdenum, lead, and zinc. In summary, the mine area is characterized by a metallic elemental suite that comprises copper, lead, zinc, gold, and silver and reflects sulfide mineralization and temperatures higher than the carbonate-oxide deposits typical of the upper plate rocks.

The mine area was further investigated by an IP survey, results of which suggest the possibility of altered rocks and (or) sulfide mineralization that extends to a depth of several hundred feet from the mine and southeast along a northwest-trending structure for at least a mile. Several other mines and prospects explore the same fault zone and have geologic settings and geochemical expressions similar to those at the New American Eagle mine. These are the Sleepy Burro group, D & W mine, the Atkinson group, and four unnamed prospects (pl. 1, fig. 3, and table 2, Nos. 3, 5, 6, 7, 8, 9, and 10).

The criteria used to define the mineral resource potential in this area (pl. 1 and fig. 2) are (1) an inferred extension of mineralized fault zones into the area and the presence of a dioritic dike swarm that may have provided mineralizing solutions, (2) the known past production of gold, silver, and copper in the area, (3) an aeromagnetic anomaly and coincident electrical data giving evidence of alteration along a north-northwest-trending structure at or near the New American Eagle mine, (4) the position high in the lower plate near the Whipple Mountains detachment fault, making the area favorable for deposition of minerals from solutions migrating along the fault, and (5) anomalous concentrations of metallic elements measured in stream sediments and panned concentrates. The area is considered to have moderate mineral resource potential for copper, lead, zinc, gold, and silver with a certainty level of B.

An area in the eastern part of the study area adjacent to the Whipple Mountains Addition Wilderness Study Area and including the area of the Copper Crest group (pl. 1, fig. 3, and table 2, No. 46) is underlain by gneiss that has been intruded locally by dikes. The prospect area is characterized by a metallic elemental suite that comprises copper, gold, and silver. The criteria used to define the mineral resource potential in this area (pl. 1 and fig. 2) are (1) permissive geologic setting similar to that which hosts mineralized zones in the western part of the study area and the presence of dikes that may have provided mineralizing solutions, (2) anomalously high amounts, in various sample media, of copper and gold, and (3) the presence of a prospect at which gold-, silver-, and copper-bearing samples were collected. The area is considered to have moderate mineral resource potential for copper, gold, and silver with a certainty level of C.

A poorly defined area that lies astride the north boundary of the wilderness area is approximately centered on the War Eagle mine (pl. 1, fig. 3, and table 2, No. 2). The area is in the lower plate of the Whipple Mountains detachment fault and may be part of a thin plate above a lower subsidiary detachment fault of smaller offset (E.G. Frost, oral commun. 1982). Normal faults striking west-northwest have been mapped in this area by W.J. Carr (written commun., 1982). The rock assemblages in the area are similar to those of the area along the west boundary (previously discussed); that is, nonmylonitic crystalline rocks intruded by a hypabyssal dike swarm. Small outcrops of gabbro have been mapped in the area, and aeromagnetic and gravity anomalies suggest additional mafic rock at depth. No evidence of pervasive surficial alteration was seen. The mine area is explored by 7 shafts, 5 trenches, and 12 pits. Few geochemical anomalies from stream sediments and panned concentrates were observed, owing partly to low relief and partly because exposed indications of mineralization are weak. However, a sample collected from a drainage in the vicinity of the War Eagle mine does contain anomalous concentrations of copper, zinc, arsenic, and molybdenum in the leachate of the intermediate magnetic fraction of panned concentrate and also contains anomalous concentrations of barite and copper in the nonmagnetic fraction. Analyses of three rock samples collected at the mine showed a metallic elemental suite of copper, lead, zinc, gold, and silver similar to that observed in the area on the west boundary but at significantly lower concentrations. Anomalous concentrations of molybdenum (30–50 ppm) were measured in two samples.

This area is best defined by geophysical data. Aeromagnetic gradients suggest a northwest-trending structure through the mine area and an east-northeast-trending structure south of the mine. An IP survey in the mine area indicates alteration to a depth of at least 1,000 ft and suggests that the alteration may increase with depth.

Criteria used to assess the mineral resource potential in the area (pl. 1 and fig. 2) are (1) an inferred extension of mineralized fault zones into the area and the presence of a dioritic dike swarm that may have provided mineralizing solutions, (2) aeromagnetic, gravity, and IP anomalies suggesting fault zones, mafic rocks, and alteration at depth, and (3) limited production from mines. The area is considered to have low mineral resource potential for copper, lead, zinc, gold, and silver with a certainty of B.

Mineralization Related to Granitic Plutons—Copper, Lead, Zinc, Gold, and Silver

Small outcrop areas of a Cretaceous granitic pluton occur along the southeast side of the study area. Copper-bearing rocks are present in or near several of these pluton outcrops, and it is probable that at the time of detachment faulting a mineral deposit related to the Cretaceous granite pluton overrode lower plate rocks. This dislocation broke up both the mineralized areas and the granite pluton along listric normal faults. Mineralization was probably associated with the detachment fault tectonic episode, as the geochemical suites observed are very similar to those in the previously discussed areas of high mineral resource potential. In addition, preexisting mineralization may have been remobilized at the time of detachment faulting.

An area of low resource potential for copper, lead, zinc, gold, and silver defines the area of dislocated granites that extends east and west from the vicinity of the Blue Cloud mine (pl. 1, fig. 3, and tables 1 and 2, No. 27) and continues to Copper Basin on the northeast. At Copper Basin, just east of the study area boundary, an extensively explored mineral deposit occurs in altered rocks adjacent to an offset portion of the pluton. Detachment faulting also appears to have provided a mechanism for redistribution and concentration of ore minerals originally emplaced with the pluton (Wilkins and Heidrick, 1982; E.G. Frost, written commun., 1982). Mineralized zones are present in altered crystalline rocks of the upper plate adjacent to outcrop areas of the granite pluton and extend downward into an intensely altered zone (chlorite-breccia zone) just below the detachment fault, indicating redistribution of metals during or after dislocation.

The granite pluton also crops out along the southeast boundary of the wilderness study area. The southernmost outcrop is near the Blue Cloud mine and the other outcrop is approximately 1 mi east-northeast of the Blue Cloud area. Semiquantitative spectrographic analyses of stream sediments, panned concentrates, and ICP analyses of the leachate from the intermediate magnetic fraction of the panned concentrates show molybdenum, copper, lead, and zinc anomalies with molybdenum being the dominant metal. Small localized areas of remobilized mineral concentrations can occur in both upper and lower plate rocks adjacent to the dislocated granite pluton. Three zones of alteration (limonitic) were identified in this area (pl. 1), possibly related to exposures of the chlorite breccia zone.

The Blue Cloud mine, which consists of 1 shaft, 4 adits, 2 trenches, and 10 prospect pits (pl. 1, fig. 3, and tables 1 and 2, No. 27), lies in the central part of this area in a hydrothermally mineralized and altered shear zone in mylonitic gneiss, near the detachment surface and high in the lower plate.

The criteria used to assess the mineral resource potential in the area (pl. 1, fig. 2) are (1) exposures of the dislocated granite pluton, (2) geochemical anomalies in molybdenum, copper, lead, and zinc, (3) presence of altered rock, and (4) existence of mining activity with production of silver and copper. This area has low mineral resource potential for copper, lead, zinc, gold, and silver with a C certainty level.

Manganese Mineralization

Manganiferous deposits in the study area are limited to upper plate Tertiary rocks and generally occur as lenticular, podiform, and irregular masses in limestone, sandstone, and volcanic breccia and as fissure filling in fanglomerate. Manganese mineralization occurs in association with the other hydrothermal alteration features and may be related to Tertiary volcanism.

There are two areas with moderate resource potential for manganese (pl. 1, fig. 2). One is centered around manganese occurrences just inside the east border of the wilderness study area. The other, which contains the Stewart mine, is a large area of hydrothermal alteration along the north border of the study area.

The manganese deposits near the east border of the study area (pl. 1, fig. 3, and table 1, Nos. 36 through 39), are in the upper plate in northwest-striking bedding and bedding-plane faults in Tertiary volcanic and sedimentary rocks that dip moderately to steeply southwest. The lenticular to podiform bodies are generally less than 8 ft wide and 25 ft long. The deposits are generally concordant with bedding, but narrow discordant stringers are common. Massive psilomelane is the dominant manganiferous mineral, but it also occurs in botryoidal form where fractures were incompletely filled. Earthy pyrolusite and hematite are also important constituents. Common gangue minerals include barite and calcite. ICP analysis of the leachate from the intermediate-magnetic fraction of panned concentrates collected in the area show a range of from 0.15 to 0.9 percent manganese.

The second manganese area is located along the north border of the wilderness study area in volcanic fanglomerates that appear to have undergone solfataric alteration. This alteration seems to be related to hot volcanic water mixing with ground water and percolating through the fanglomerates. This altered area contains from 0.2 to 0.3 percent manganese in stream-sediment samples and from 0.7 to 1.2 percent manganese in the leachate of the intermediate magnetic fraction of panned concentrates. Zinc, arsenic, lead, copper, and barium were also anomalously high in these samples, suggesting an epithermal mineralizing event. Bedrock of two types was sampled: siliceous manganese ore, and red and brown iron-oxide-stained jasperoid, both from fanglomerates. Semiquantitative spectrographic analysis of the manganese-rich sample shows anomalous amounts of silver (50 ppm), arsenic (300 ppm), barium (greater than 0.5 percent), beryllium (10 ppm), copper (3,000 ppm), molybdenum (100 ppm), lead (2,000 ppm), tungsten (100 ppm), and zinc (300 ppm)—a suite of elements related to epithermal hot-spring-type manganese deposits elsewhere (Marsh and Erickson, 1974). The jasperoid sample contains a similar suite excluding the silver, beryllium, and tungsten, but concentrations were significantly lower.

At the Stewart mine (pl. 1, fig. 3, and table 1, No. 1), the manganese occurs as fissure fillings of pyrolusite with subordinate psilomelane. Hematite, limonite, and calcite are common gangue minerals. The thickest part of this deposit measures 3.5 ft. Fractures that localized the mineralization strike from N. 15° to N. 40° and dip southwest; they can be traced only a few tens of feet. Associated alteration appears to be of dominantly siliceous character.

The criteria used to assess the mineral resource potential in these areas (pl. 1, fig. 2) are (1) mines and prospects exposing manganese minerals, (2) solfataric alteration, and (3) proximity to Tertiary volcanic rocks. These areas have moderate mineral resource potential for manganese with a certainty level of C.

Decorative Building Stone

Thin-bedded to very thin bedded limestone, cherty limestone, and sandy limestone crop out in many places in the study area. Sandy limestone has been quarried only in the southern part of the study area. The deposit covers an estimated 250 acres (pl. 1, fig. 3, and table 1, No. 15). The flagstone-like material is commonly tan to gray with occasional reddish-stained laminae and partings. Individual fragments range in size from a few square inches to rare fragments larger than 2 sq ft and in thickness from less than 0.5 in. to 4 in. Two varieties of the stone occur in this area; a weathered-face surficial type consisting of a rough, iron-oxide-stained, cherty variety, and a split-face type that is obtained from unweathered material beneath the surface. Because the present quarry extends to a depth of 10 ft, more of the split-face type exists than weathered-face type, although the latter may be more desirable as a decorative facade than the split-face type. The split-face stone could also be used decoratively, but larger fragments would probably be more widely used as flagstones. At least one attempt has been made to extract this material, apparently without commercial success (Ridenour and others, 1982a).

The criteria used to assess the mineral resource potential in this area are (1) suitable rock type of thin-bedded, cherty limestone and sandy limestone and (2) an identified resource of 11,000 tons of building stone. This area has a high mineral resource potential for decorative building stone with a certainty of D.

Other Rock Products

Sand and gravel are present in the study area in alluviated washes and fans, and they are potential resources for local construction, such as in the Lake Havasu area. Rock useful for riprap for dam or other local water projects is found throughout the central part of the study area in the lower plate of the Whipple Mountains detachment fault, east of the mylonitic front and below the chlorite breccia zone. Most of these products can also be found outside the wilderness study area boundary. The entire area has a low mineral resource potential for accumulations beyond the extent of known occurrences of sand and gravel and other rock products suitable for construction with a certainty level of D.

Uranium

Two areas of potential uranium mineralization occur in the eastern part of the study area and enclose areas that contain Tertiary sedimentary rocks (including lacustrine sedimentary rocks) and volcanic rocks of the upper plate of the Whipple Mountains detachment fault (pl. 1, fig. 2). Coney and Reynolds (1980) discuss uranium in these types of rocks. Two formations permissive for hosting uranium deposits are present: the Gene Canyon Formation and the Copper Basin Formation (Davis and others, 1980). These formations are predominantly red sandstone, conglomerates, and siltstones, with interbedded andesitic volcanic rocks—a permissive environment for sandstone uranium deposits (Turner-Peterson and Hodges, 1986). Alteration in the volcanic rocks appears to be solfataric and could have provided a mechanism for redistribution and localization of any uranium concentrations. Ground scintillometer readings taken at sample-collection sites during this study were anomalously high in these areas and anomalously high concentrations of uranium were detected in the National Uranium Resource Evaluation (NURE) aeroradiometric data (J.K. Otton, written commun., 1982). The NURE aeroradiometric data generally show moderate potassium and high uranium concentrations which in this region commonly characterize uranium-enriched sedimentary rocks. Geochemical analyses do not support high or moderate resource potential.

Criteria used to assess the mineral resource potential in these areas (pl. 1, fig. 2) are (1) favorable NURE data, (2) favorable host rocks, (3) ground scintillometer readings, and (4) solfataric alteration. These areas have a low mineral resource potential for uranium with a certainty level of C.

Oil and Gas

Although the Whipple Mountains are along the extrapolated trend of the western overthrust belt, which elsewhere in the Cordillera contains oil and gas in Paleozoic and Mesozoic strata, the study area is considered unfavorable for oil and gas. Scott (1983) determined the oil and gas potential to be low to zero in this study area. Exposed relations in the Whipple Mountains and surrounding ranges suggest little likelihood that Paleozoic or Mesozoic strata are present in the study area beneath thrusts; even if such rocks were present, they would undoubtedly be metamorphosed and barren of oil or gas. The Whipple Mountains Wilderness Study Area has no resource potential for oil and gas with a certainty level of D.

Geothermal Resources

The crystalline and volcanic rocks in the study area, as well as the mineralizing fluids, were heated by sources that have been cool for over 20 million years. There is no geothermal energy resource potential in the Whipple Mountains Wilderness Study Area (Blankenship and Bentall, 1965; Higgins, 1981; Muffler, 1979) with a certainty level of D.

Mineral and Energy Resource Potential of the Whipple Mountains Addition Wilderness Study Area

An area around the Blue Heaven and Blue Heaven Extension group of prospects and extending over the entire Whipple Mountains Addition Wilderness Study Area (pl. 1, fig. 3, and table 2, Nos. 52 and 53) is underlain by gneiss that has been intruded locally by dikes. The prospect areas are characterized by a metallic elemental suite that comprises copper, gold, and silver. The criteria used to define the mineral resource potential in this area (pl. 1 and fig. 2) are (1) permissive geologic setting similar to that which hosts mineralized zones in the Whipple Mountains Wilderness Study Area and the presence of dikes that may have provided mineralizing solutions, (2) anomalously high amounts, in various sample media, of copper and gold, and (3) the presence of prospects at which gold-, silver-, and copper-bearing samples were collected. The entire Whipple Mountains Addition Wilderness Study Area has moderate mineral resource potential for copper, gold, and silver with a certainty level of C.

Sand and gravel are present in the Whipple Mountains Addition Wilderness Study Area in alluviated washes and fans, and they are potential resources for local construction, such as in the Lake Havasu area. These products can also be found outside the study area. The entire Whipple Mountains Addition Wilderness Study Area has a low mineral resource potential for accumulations beyond the extent of known occurrences of sand and gravel and other rock products suitable for construction with a certainty level of D.

Exposed geology in the Whipple Mountains and surrounding ranges suggest little likelihood that Paleozoic or Mesozoic strata are present in the study area beneath thrusts; even if such rocks were present, they would undoubtedly be metamorphosed and barren of oil or gas. The Whipple Mountains Addition Wilderness Study Area has no resource potential for oil and gas with a certainty level of D.

The crystalline and volcanic rocks in the study area, as well as the mineralizing fluids, were heated by sources that have been cool for over 20 million years. There is no geothermal energy resource potential in the Whipple Mountains Addition Wilderness Study Area (Blankenship and Bentall, 1965; Higgins, 1981; Muffler, 1979) with a certainty level of D.

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APPENDIXES; TABLE 2

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LEVELS OF RESOURCE POTENTIAL

- H **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.
- M **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 reasonable likelihood for resource accumulation, and (or) where an application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.
- L **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 permissive. This broad category embraces areas with dispersed but insignificantly mineralized rock, as well as areas with little or no indication of having been mineralized.
- N **NO** mineral resource potential is a category reserved for a specific type of resource in a well-defined area.
- U **UNKNOWN** mineral resource potential is assigned to areas where information is inadequate to assign a low, moderate, or high level of resource potential.

LEVELS OF CERTAINTY

- A Available information is not adequate for determination of the level of mineral resource potential.
- B Available information only 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.

LEVEL OF RESOURCE POTENTIAL →

A	B	C	D
U/A UNKNOWN POTENTIAL	H/B HIGH POTENTIAL	H/C HIGH POTENTIAL	H/D HIGH POTENTIAL
	M/B MODERATE POTENTIAL	M/C MODERATE POTENTIAL	M/D MODERATE POTENTIAL
	L/B LOW POTENTIAL	L/C LOW POTENTIAL	L/D LOW POTENTIAL
			N/D NO POTENTIAL

LEVEL OF CERTAINTY →

Abstracted with minor modifications from:

Taylor, R.B., and Steven, T.A., 1983, Definition of mineral resource potential: Economic Geology, v. 78, no. 6, p. 1268-1270.
Taylor, R.B., Stoneman, R.J., and Marsh, S.P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40-42.
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RESOURCE/RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range	
	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, V.E., 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 by the U.S. Geological Survey in this report

EON	ERA	PERIOD		EPOCH	AGE ESTIMATES OF BOUNDARIES IN MILLION YEARS (Ma)
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	[1]~570
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 Ma also called Precambrian, a time term without specific rank.
[2]Informal time term without specific rank.

Table 2. Mines and prospects in the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas and vicinity, San Bernardino County, California

[*, outside of study area boundary]

Map no. (fig. 3; pl. 1)	Name (commodity)	Summary	Workings and production	Sample and resource data
1	Stewart mine	Manganese-bearing fissure veins strike northwest and dip steeply to the northeast in fanglomerate. The veins range in thickness from a few inches to as much as 5 ft, but thin down dip and can be traced for about 200 ft along strike. The manganese oxides, identified as pyrolusite and psilomelane (Holmes, 1954a), occur as soft, sooty masses and, in incompletely filled fractures, as botryoidal masses.	Three adits and associated open cuts total about 190 ft in length, and numerous prospect pits and bulldozer scrapings. The mine has produced a minimum of 126 long tons of manganese ore that contained between 35.84 percent and 39.66 percent manganese (USBM files).	Eleven chip samples ranged from 6 to 64 percent manganese. Approximately 2,600 long tons of subeconomic resources averaging 12 to 15 percent manganese are inferred based on length of exposure (200 ft), probable depth (90 ft), and average thickness (2 ft) of the veins at the three main workings. Considerable hand sorting would be required to achieve a grade of 35 percent. Because of a lack of extensive resources, the mine is not likely to be active in the future.
2	*War Eagle mine (Old Roth, Virginia)	Altered and mineralized shear zones in Precambrian gneiss and Tertiary and Cretaceous mafic to silicic dikes. Mineralized structures generally trend northwesterly and dip steeply to the southwest, and contain chrysocolla in a gangue of quartz, hematite, limonite, and sheared country rock. Minor pyrite is visible in dump material and chalcopyrite is reported at depth (USBM files). Surface outcrops are highly leached and chloritically altered. Induced polarization (IP) surveys (Marsh and others, 1982) identified a near vertical zone of increased polarization that extends to a depth of at least 1,000 ft near the War Eagle shaft.	The main shaft is reported as 150 ft deep (Elliott, 1943); six inclined shafts range from 15 to 90 ft deep. Five trenches or open cuts and 12 prospect pits. USBM records show a small tonnage, produced in 1957, that contained 1 oz silver and 465 lb copper.	Twenty-two samples: One chip sample contained 0.01 oz/ton gold, 3 samples (2 chip, 1 grab) contained 0.2 oz/ton silver; 12 samples (all chip) contained from 0.01 to 0.17 percent copper. The presence of a large polarizable zone at depth suggests continuation of mineralization below that developed from the main shaft. However, the zone may not attract exploration interest without an indication of coproduct gold.
3	Sleepy Burro group (Whipple Mountain mine, Braintruster mine)	The claim group is mainly underlain by Precambrian gneiss intruded by a chemically bimodal suite of porphyritic dikes except at the northwest end which is underlain by a klippe of Tertiary volcanic rocks. Chrysocolla occurs in fractures that dominantly trend N. 40° W. and along contacts between the porphyritic dikes and country rock.	Eight shafts, one of which was reported to be 80 ft deep, one short adit, and numerous prospect pits. USBM files show 1 oz silver and 69 lb copper produced from the Braintruster mine in 1949, and a total of 4.4 oz gold, 2 oz silver, and 6,905 lb copper from the Whipple Mountain mine in 1911 and 1913.	Twenty-four samples: One chip sample contained 0.02 oz/ton gold and 2 grab samples had 0.03 and 0.45 oz/ton gold; 12 samples contained silver ranging from 0.2 to 0.4 oz/ton; 10 chip samples contained from 0.01 to 2.5 percent copper, and 7 grab samples from 1.2 to 6.2 percent copper. Wright and others (1953) reported 5 to 10 percent copper and $8/ton gold (at $35/oz) from a 1- to 2-ft-wide zone in a dike on the Braintruster. The prospect may warrant further exploration; some of the workings appear on strike with a 5,000-ft-long polarizable zone across the New American Eagle mine.

Table 2. Mines and prospects in the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas and vicinity, San Bernardino County, California—*Continued*

Map no. (fig. 3; pl. 1)	Name (commodity)	Summary	Workings and production	Sample and resource data
4	*New American Eagle mine	A mineralized fault strikes N. 35° W. and dips about 80° SW. in foliated gneiss intruded by porphyritic bimodal dikes. A highly chloritized dike follows the fault; quartz sericite alteration extends a short distance into the wallrock from the fault zone. Pyrite, chalcopyrite, and chalcocite were reported at depth. Stevens (1911) reported a main vein 10 to 20 ft wide and 2,000 ft long with several smaller, parallel veins. Wright and others (1953) reported a 20-ft-thick lens that extends to a depth of 120 ft from just below the surface and which was traced for 50 ft along strike. IP survey lines (Marsh and others, 1982) identified a polarizable zone about 5,000 ft long, that extends to a depth of 980 ft, which passes directly through the main shaft.	Two shafts, one reportedly 300 ft deep (Wright and others, 1953); several cuts and prospect pits; and concrete millsite foundations. Wright and others (1953) reported 700 tons of ore, produced prior to 1918, that averaged about 8 percent copper. Eric (1948) reported 571 tons that contained 10.7 percent copper produced prior to 1918. USBM files show production from 1912, 1918, 1919, and 1935 that averaged 0.05 oz/ton gold, 0.12 oz/ton silver, and 6.2 percent copper.	Six samples: one grab sample contained 0.9 percent copper; four chip samples contained from 1.0 to 2.9 percent copper; three chip samples contained from 0.2 to 1.4 oz/ton silver; two chip samples contained 0.03 and 0.44 oz/ton gold. No resources could be calculated because underground workings were unsafe to enter. Wilson (1918) estimated 900 tons of ore averaging 4.17 percent copper in the main shaft, and 1,175 tons of dump material of 3.61 percent copper. Eric (1948) reported a 90,000-ton resource with 3.8 percent copper. Because of the length and depth of the polarizable structure and past production, the mine warrants further exploration.
5	*Prospect	Gneiss is altered along and adjacent to a northwesterly trending shear zone. The 6-ft-thick zone is limonitic with chloritic alteration above and siliceous alteration with chrysocolla below.	Four prospect pits.	Three samples: two contained no gold or silver, and 0.01 and 0.27 percent copper; one sample contained 0.05 oz/ton gold, 0.4 oz/ton silver, and 0.91 percent copper.
6	Prospect	Chrysocolla occurs as coatings in a hematitic shear zone that trends northwesterly in felsite.	One 27-foot adit.	One sample: no gold, 2 oz/ton silver, and 2.25 percent copper.
7	Prospect	Minor chrysocolla occurs in an altered zone adjacent to a shear that trends northwesterly in gneiss.	One shallow shaft.	One sample: no gold or silver detected; 0.01 percent copper.
8	Prospect	A chrysocolla-stained mafic dike intruded into granite gneiss.	One prospect pit.	One sample: no gold or silver detected; 1.70 percent copper.
9	*D & W mine	Foliated gneiss is intruded by felsic to mafic dikes that range from a few inches to several feet thick. The general trend of the dike swarm is northwesterly. Deposits at depth are reported to be associated with a quartz porphyry dike (Wright and others, 1953) and a porphyritic dike in diorite (Cloudman and others, 1919; Tucker and Sampson, 1931). The ore contained azurite, malachite, and gold (Cloudman and others, 1919). Small, scattered pods of chrysocolla are present in fractures and along contacts between dikes and country rock in the main adit. IP lines (Marsh and others, 1982) detected no polarizable bodies in the vicinity of the D & W shaft.	One shaft reported to be 750 feet deep with more than 5,000 ft of underground workings (Wright and others, 1953), one 600 ft adit, and several prospect pits. USBM files show 75 tons of ore, produced in 1913, that yielded 7.98 oz gold and 2 oz silver; copper content, if any, was not recorded.	Twelve samples: Six of 11 chip samples contained from 0.01 to 0.16 oz/ton gold; 11 chip samples ranged from 0.2 to 0.4 oz/ton silver, and from 0.01 to 1.7 percent copper; 1 grab sample contained 1.03 oz/ton gold, 0.2 oz/ton silver, and 5.2 percent copper. No resources were defined because underground workings were unsafe to enter. Vredenburgh and others (1981) reported ore valued at between $10 and $14/ton at $20.67/oz gold prices.

10	Atkinson group (patented)	Gneiss is intruded by felsic and mafic dikes. Shear zones and dikes trend about N. 40° W. Chrysocolla occurs as fracture coatings in isolated, small pods generally associated with hematite.	Eight prospect pits and three shafts.	Seven samples: one grab sample had 0.18 oz/ton gold; silver ranged from none to 1.0 oz/ton; copper ranged from 1.3 to 6.95 percent.
11	Bluebird prospect	Chrysocolla and hematite occur as fracture coatings in mylonitic gneiss. Two discontinuous shear zones strike and dip N. 10° E., 45° SE. and N. 80° W., 60° NE.	One 75-ft adit and a vertical shaft approximately 30 ft deep; about 17 prospect pits and bulldozer cuts.	Thirteen samples: no gold to 0.04 oz/ton; 0.2 to 0.8 oz/ton silver, 0.2 to 5.4 percent copper.
12	Dickie prospect	A discontinuous veinlet of chrysocolla as thick as 0.4 ft trends northwesterly in gneiss and mafic dikes intruded by quartz diorite.	One prospect pit and a 10-ft-deep shaft.	Two samples: trace gold; trace and 1.6 oz/ton silver; 0.04 and 1.3 percent copper.
13	Turk Silver mine	Malachite, chrysocolla, hematite, and barite occur as veinlets, pods, and fracture coatings in 1- to 3-ft-thick breccia of a listric fault. The fault, which strikes N. 60° W. and dips 60° NE., can be traced for approximately 450 ft and occurs between amygdaloidal andesite and breccia flows, and limestone, all of Tertiary age. A secondary structure, which marks the contact between the limestone and overlying sandstone, ranges from 2 to 4.5 ft thick and can be traced for about 100 ft along strike. This zone contains barite veinlets, drusy quartz, limonite, and brecciated country rock.	Three small shafts, 2 adits, and 21 prospect pits. The total length of underground workings is estimated at about 550 ft.	Eighteen chip samples: one sample contained 0.02 oz/ton gold, nine contained from 0.8 to 4.4 oz/ton silver, and seven contained from 0.04 to 3.5 percent copper. Approximately 2,000 tons of subeconomic resources that average 2.4 oz/ton of silver and 0.6 percent copper are inferred in the main zone. It is to unlikely that sufficient resources are present at depth to warrant further investigation.
14	Twin Lode mine	Pods and veinlets of quartz, malachite, chrysocolla, barite, hematite, and pyrolusite occur in breccia of a listric fault and associated fault splays and tension gashes. The fault strikes N. 60° W. and dips 60° NE., separating Tertiary volcaniclastic and sedimentary rocks. The fault contact can be traced for about 400 ft along strike and ranges from 0.2 ft to 3 ft thick. This fault appears to be the same fault as at the Turk Silver mine.	One main adit, about 140 ft long, and a short adit(?) or cut on a separate fault splay; one trench and two prospect pits.	Eleven samples: One grab sample contained 4.0 oz/ton silver and 0.07 percent copper; 10 chip samples contained 0.3 to 10.8 oz/ton silver; 9 of these samples contained 0.04 to 0.10 percent copper. Approximately 4,100 tons of subeconomic resources that average 7 oz/ton silver and 0.10 percent copper are inferred. Considering the erratic nature of the most mineralized parts of the fault, it is unlikely that sufficient additional resources are present to warrant further investigation.
15	Decorative stone property	Buff, gray, and rust-colored platy polygons of cherty and sandy limestone occur over an area of about 250 acres. The individual pieces, deemed usable as a decorative facing, should measure 0.5 ft on two sides of any polygon and range from 0.1 to 0.3 ft thick. Two varieties are present: a weathered-face type with an iron-oxide stained, cherty surface, and a split-face type in slabs which generally occur below the surface.	One small quarry approximately 30 ft long and 10 ft deep. No known record of production; however, pallets in the area suggest some rock may have been shipped.	Approximately 1,000 tons of usable weathered-face rock is inferred for the 250-acre area; depending upon the depth of weathering, the amount of usable split-face rock may exceed 10,000 tons. The site may attract future interest depending on market development and competition.

Table 2. Mines and prospects in the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas and vicinity, San Bernardino County, California—*Continued*

Map no. (fig. 3; pl. 1)	Name (commodity)	Summary	Workings and production	Sample and resource data
16	*Riverview mine (Tuscarora, Ethel Leona)	Chloritic breccia zones that contain hematite, specular hematite, chrysocolla, and malachite occur along listric faults that strike northwest and dip northeast. According to Cloudman and others (1919, p. 791) and Wright and others (1953), free-milling gold is also present. The most prominent of these faults, which separates granite gneiss on the foot wall from andesite flows on the hanging wall, can be traced for about 1,300 ft along strike. A less mineralized fault to the north of the main fault can be traced for more than 2,000 ft.	Twenty-five prospect pits and one large open pit; 13 trenches; 3 inclined and 4 vertical shafts; 4 adits.	Eighty-seven samples: copper content ranged from 0.01 to 4.4 percent in 74 samples, 9 of which contained 1.0 percent or more; gold ranged from 0.01 to 0.42 oz/ton in 19 samples; silver ranged from 0.2 to 0.4 oz/ton in 18 samples. The pinch and swell characteristics of mineral occurrences along the fault zones do not allow a reasonable estimate of resources. Based on the average gold, silver, and copper content, coupled with the high cost of underground mining, the property may not warrant further investigation.
17	Prospect	A 2-ft-thick chloritic shear zone with silicified stringers of iron oxide and chrysocolla strikes N. 85° E. and dips 23° NW. in altered granite gneiss. The zone is exposed for 20 ft along strike and 10 ft downdip.	One 60-ft-long inclined shaft, one prospect pit, and several bulldozer cuts.	Two samples: each contained a trace of gold, a trace and 1.6 oz/ton silver, and 0.04 and 1.3 percent copper.
18	Prospect	A 2-ft-thick, 10-ft-long, iron-oxide stained breccia zone strikes N. 30° E. and dips 64° SE. in granite gneiss.	One prospect pit.	One sample: no gold, silver, or copper detected.
19	Double M No. 1	Three chloritic shears, which range in thickness from 0.5 ft to 2 ft, occur in granite gneiss; the shears contain quartz blebs. The zones strike and dip N. 45° W., 80° SW.; N. 15° W., 27° SW.; and N. 56° W., 65° NE. The largest of the structures is exposed for 50 ft.	Three trenches and two prospect pits.	Three samples: one contained 0.2 oz/ton silver; no other silver, gold, or copper detected.
20	Lucky Green group	Granite gneiss and mafic intrusive rocks were intruded by a locally foliated adamellite plug. Scattered thin stringers and veinlets of pyrite and chalcopyrite rimmed by chrysocolla occur throughout the mine area.	Four open cuts, several prospect pits, and two short adits; leach vats were replaced by newer 3-compartment tanks.	Twelve chip and grab samples: five chip samples contained 0.2 oz/ton silver, seven contained from 0.01 to 6.5 percent copper; three of five grab samples contained from 0.2 to 0.8 oz/ton silver and all five contained copper ranging from 0.01 to 7.5 percent. Eleven channel samples of crushed rock in the newer tank and small stockpile averaged 0.32 percent copper (silver was detected in only two of these samples). The leach tank contains an estimated 1,350 tons of measured, subeconomic resources and a small stockpile an additional 600 tons of inferred subeconomic resources. The widespread occurrence of copper at this site suggests additional resources may be present, and the property may warrant further exploration.
21	Thunderbird prospect	A 2.5- to 6.0-ft-thick, sheared mafic dike in granite gneiss contains stringers of malachite, chalcopyrite, limonite, hematite, and jasperoid. The zone strikes N. 26° to 55° W. and dips 35° to 68° NE.	A 55-ft inclined shaft, a vertical shaft caved at approximately 45 ft, and a 33-ft adit.	Six samples: no gold detected; five contained 0.2 to 0.4 oz/ton silver; copper ranged from 0.28 to 1.3 percent.

22	Black Mesas prospect	A 1.3- to 6.5-ft-thick, silicified to friable, chloritic, limonite- and malachite-bearing shear zone approximately 170 ft long in granite gneiss intruded by mafic dikes. The zone strikes N. 62° W. and dips 55° to 65° NE.	One 15-ft adit with a raise to the surface, and one 23-ft adit.	Four chip samples: three contained 0.01 to 0.11 oz/ton gold; silver ranged from 0.4 to 1.4 oz/ton; three contained copper from 0.07 to 0.77 percent.
23	Lizard group (mine)	Several silicified shear zones contain chrysocolla and sulfide minerals [pyrite and chalcopyrite(?)]. Workings and minerals of interest occur along a northwest trending zone approximately 4,200 ft long and 650 ft wide in granite gneiss intruded by felsic to mafic dikes. The shear zones strike N. 20° to 55° W. and dip from 33° to 85° NE.	One 130-ft inclined shaft; five shafts ranging from 10 to 20 ft deep; one 65-ft adit; several prospect pits and trenches.	Twenty-one samples (15 chip and 5 grab): no gold detected; 7 samples contained from 0.2 to 0.4 oz/ton silver; 15 chip samples contained 0.01 to 4.6 percent copper, 4 of which had more than 1 percent. Four grab samples contained 0.01 to 10 percent copper. No arsenic was detected in four samples analyzed.
24	Golden Arrow group (prospect)	A 3- to 5-ft-thick, chloritic shear zone strikes N. 45° E. and dips 25° to 60° NW. in granite gneiss. The zone contains hematite and chrysocolla near the surface and pyrite and chalcopyrite at depth (90 ft) and can be traced for about 90 ft along strike.	One 90-ft inclined shaft and two prospect pits.	Six samples: three contained 0.01 to 0.03 oz/ton gold and 0.2 to 0.4 oz/ton silver; five samples had 0.10 to 0.66 percent copper.
25	Prospect	Detachment fault surface strikes N. 88° E. and dips 17° SE. A 3-ft-thick zone contains stringers and veinlets of chrysocolla. Predominant lithology is chlorite breccia below the detachment fault and diorite and gneiss above it.	One 134-ft trench, one 25-ft inclined shaft, one vertical shaft, and one short adit.	Two samples: no gold detected; 0.2 and 0.3 oz/ton silver; 1.1 and 5.1 percent copper.
26	Blackjack group (prospect)	A 3,500-ft-long, 2- to 6-ft-thick fault with hematite, minor chrysocolla, and barite, and an altered, fractured shear zone with minor chrysocolla and barite; both occur in gneiss. The main zone strikes N. 49° W. and dips 50° to 70° NE.	Nine prospect pits, one trench, and a bulldozed area 200 to 300 ft in diameter.	Eight samples: no gold detected; one contained 0.2 oz/ton silver; copper ranged from 0.04 to 0.65 percent; seven samples contained 0.07 to 3.49 percent barium.
27	*Blue Cloud mine	A 1.3- to 20-ft-thick shear zone in mylonitic gneiss strikes from N. 10° to 30° W. and dips between 36° and 74° NE., and can be traced for about 2,000 ft. Localized pods, stringers, and veinlets of chrysocolla, malachite, specular hematite, and limonite occur in the zone and adjacent country rock.	Four adits and an inclined shaft totaling about 280 ft long, 10 prospect pits, and 2 trenches. A powder bunker, hoist foundation, and mill(?) foundations are located east of the main workings. USBM records show 3 tons of ore was produced in 1950, that yielded 1 oz silver and 254 lb copper.	Fifty samples: One grab sample contained 0.01 oz/ton gold and 0.44 percent copper; 49 chip samples contained from 0.06 to 3.25 percent copper; no significant gold or silver was detected in the chip samples. Identified (indicated and inferred) resources total approximately 235,000 tons that average 0.48 percent copper. Because of the high cost of underground mining and lack of precious metal content, these resources are subeconomic at current (1986) prices, but the mine may warrant further investigation.
28	Red Eagle group (Pasadena shaft, Horseshoe tunnel) (prospect)	Sheared and faulted mylonitic gneiss contains hematite, pyrite, and sparse chrysocolla along northwesterly trending fractures. A small structure in the north adit strikes N. 10° to 25° W. and dips 65° SW. A larger structure in the main adit strikes N. 45° to 55° W. and dips 35° NE.	Two adits totaling 280 ft long, two prospect pits, and two shafts, one of which is reported to be 150 ft deep (Bancroft, 1911, p. 69).	Eleven samples: Five chip samples contained 0.02 oz/ton silver and 1 grab sample had 0.4 oz/ton silver; copper ranged from 0.15 to 1.7 percent in 10 chip samples; 1 grab and 1 chip sample each had 0.01 oz/ton gold.

Table 2. Mines and prospects in the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas and vicinity, San Bernardino County, California—*Continued*

Map no. (fig. 3; pl. 1)	Name (commodity)	Summary	Workings and production	Sample and resource data
29	Prospect	Altered shear zones in chloritic gneiss contain hematite and various amounts of chrysocolla, manganese dendrites, and limonite; some chlorite breccia present.	Five prospect pits and one shallow shaft.	Five samples: all contained a trace of gold; silver content ranged from a trace to 0.4 oz/ton, and copper from a trace to 2.1 percent.
30	Prospect	Generally northwest-trending, northeast-dipping shear zones exposed for less than 10 ft in intensely altered, decomposed, chloritic gneiss; the zones range from 3 to 6 ft thick, contain secondary copper minerals, iron oxides including specular hematite, and are probably associated with the detachment fault. The shear zone exposed at the shaft strikes N. 50° W. and dips 65° NE. Shear zones in the adit strike and dip N. 30° W., 75° SW.; N. 50° W., 28° NE.; and N. 75° E., 15° NW.	One 47-ft adit and a 20-ft-deep, partly caved inclined shaft.	Three samples: 0.16, 0.71, and 0.92 percent copper.
31	*Sunday Brass prospect	Two banded, mineralized breccia zones, 50 ft apart and 5.3 to 6.5 ft thick, and several thinner zones strike N. 35° to 40° W. and dip 70° to 75° NE. along a 300- to 400-ft-long outcrop in a klippe of andesite. The zones contain abundant intergrowths of barite with interstitial calcite, quartz, and iron and manganese oxides. A subparallel, 400-ft-long, 5- to 6-ft-thick zone 200 ft to the southwest contains secondary copper minerals in a fractured, amygdaloidal andesite.	One caved shaft, one caved adit, and two prospect pits.	Eleven samples: a sample of barite-rich andesite breccia contained 4.7 oz/ton silver, 0.013 percent lead, and 35.2 percent barite ($BaSO_4$). Two other samples of andesite breccia contained 0.9 oz/ton silver, 0.035 percent lead, 0.024 percent zinc, 20.4 and 20.4 percent barite, and 4.0 oz/ton silver, 0.028 percent lead, and 38.1 percent barite. Four samples from the subparallel zone averaged less than 0.1 oz/ton silver.
32	*Prospect	A shear zone in a detachment fault between lower plate gneiss and upper plate volcanic rocks is 2 ft thick, strikes N. 70° E. and dips 45° SE, and contains abundant chrysocolla. The zone is exposed for 15 ft downdip.	A 15-ft, steeply inclined shaft.	One sample contained 0.69 percent copper.
33	*Nickel Plate mine	Two prominent shear zones trend northwesterly and dip to the northeast in highly fractured, altered quartz monzonite. The zones, which range in thickness from a few inches to about 2 ft, contain small pods and fracture coatings of chrysocolla; limonite and hematite stain these zones where exposed on the surface. Quartz sericite alteration is in the hanging walls and foot walls of these zones.	Two adits with a total of about 640 ft of crosscuts and drifts; four shallow, inclined shafts; and seven prospect pits. USBM files indicate 326 tons of ore, produced between 1929 and 1941, that averaged 0.83 oz/ton gold, 0.09 oz/ton silver, and 1.2 percent copper.	Twenty-two samples: gold content ranged from 0.02 to 0.4 oz/ton in 11 of the samples; silver (0.2 oz/ton) was in 6 samples; copper content ranged from 0.10 to 5 percent. Approximately 3,000 tons of of inferred, subeconomic resources in the two zones averages 0.02 oz/ton gold and 1.4 percent copper. Because the extent of these structures is limited by faults, it is unlikely that the mine warrants further exploration.

34	*Ruthie prospect (Homer claims)	Foliated, lower plate, chlorite schist and gneiss with randomly oriented veins and zones of hydrothermally altered rock contain one or more of the following: earthy limonite and hematite, specular hematite, and epidote. The zones range from 1.0 to 4.2 ft thick, are exposed for 10 to 20 ft, and trend N. 30° E. to N. 35° W. A klippe of andesite contains a 40-ft-long by 3.1-ft-thick exposure of copper silicates and iron oxides which strikes N. 25° E. and dips 15° SE.	Seven prospect pits.	Seven samples: one sample of andesite contained 0.05 oz/ton silver and 0.53 percent copper; three samples of gneiss and schist contained from 0.0043 to 0.05 percent copper.
35	Prospect	A 0.25-ft-thick, nearly horizontal zone that contains chrysocolla occurs in chlorite breccia just below the contact between upper and lower plate rocks.	One prospect pit.	One sample contained a trace of gold, 0.2 oz/ton silver, and 1.95 percent copper.
36	*Van Horn mine	Psilomelane and pyrolusite in a gangue of barite, calcite, limonite, hematite, quartz, and brecciated country rock occur along an antithetic bedding plane fault in Tertiary sedimentary strata, mainly limestone. Lenses and pods of manganese from 2 to 8 ft thick crop out mainly along the ridge crest in the vicinity of the main workings. The fault, which strikes N. 40° W. and dips from 45° to 75° SW., can be traced for approximately 1,500 ft along the surface.	Workings consist of three stopes to the surface from a drift which is connected by a winze to a crosscut adit that once served as a haulage way. A small headframe, stulls, and air pipes are located near the stope openings. Approximately 20 prospect pits and minor excavations lie along strike of the fault. Morse and Hudson (1918, p. 3) report 60 long tons of 45 percent manganese ore were ready for shipment in 1918. USBM property files (Trengove, 1958) indicated approximately 700 long tons of ore with manganese content ranging from 25 to 42 percent was shipped to the Wendon, Ariz., stockpile from 1953 to 1955.	Nineteen samples: Eighteen chip samples contained between 0.1 and 28.8 percent manganese (most contained less than 1 percent manganese). Because the structure appears to diminish to the north, the property may not warrant further exploration.
37, 38, and 39	*Monarch, *Manganese King, and Monument King mines	Massive to botryoidal psilomelane occurs along bedding plane faults in Tertiary sedimentary strata, mainly limestone. Lenses and pods of manganese 1 to 10 ft wide and 50 to 100 ft long, are commonly associated with barite, calcite, quartz, brecciated limestone, and hematitic jasper. The main limestone unit strikes N. 20° to 50° W., dips from 50° to 80° SW., and crops out for approximately 7,000 ft as a prominent ridge. Toward the southeast part of this outcrop, the limestone splits into two narrow, parallel units.	Seven adits and underground stopes, 7 trenches, and 18 pits, cuts, and shallow shafts. Conflicting, incomplete records show 160 tons of 46 percent manganese produced in 1917-1918 (Trask, 1950; Wright and others, 1953; Holmes, 1954b) and 200 tons of 45 percent manganese (years unspecified) (Tucker and Sampson, 1943). Trengove (1960) reported the Monarch produced 1,100 tons that ranged from 29.8 to 42.1 percent and the Manganese King-Monument King 600 tons that ranged from 29 to 46 percent during World War I and intermittently into the early 1950's.	Twenty-five samples: Twenty-four chip samples contained between 0.03 and 22.8 percent manganese, only 1 of which had greater than 20 percent manganese. Because of the length and persistence of the manganese-bearing zone, these properties may warrant further exploration.

Table 2. Mines and prospects in the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas and vicinity, San Bernardino County, California—*Continued*

Map no. (fig. 3; pl 1)	Name (commodity)	Summary	Workings and production	Sample and resource data
40	Prospect	One- to 2-ft-thick, intensely sheared, chlorite breccia zone strikes northeast to east and dips 30° to 50° N. along the contact between upper and lower plate rocks. The zone is exposed for 100 ft and is composed of green to brown, iron-oxide-stained metamorphosed granitic rock with minor secondary copper minerals and calcite. At the collar of the larger of the two inclined shafts, the zone strikes N. 69° W. and dips 35° NE.	Two inclined shafts, one about 100 ft long and the other 10 ft long.	Four samples: two samples contained 0.06 and 0.01 oz/ton gold, and 0.35 and 0.48 percent copper.
41	*Helen prospect	Localized pegmatite dikes and siliceous zones parallel to foliation in chloritically altered crystalline rocks. The zones strike N. 50° to 80° W. and dip 70° SW. to vertically, range from 3 to 10 ft thick, and are exposed for up to 100 ft of length. A few dissected alluvial fans and poorly sorted fluvial deposits are perched along the flanks of ridges.	Two pits and a 10-ft-long placer drift.	Four lode samples and one placer sample contained no significant amounts of gold or silver.
42	Prospect	Chlorite breccia below contact with overlying volcanic breccia. Chrysocolla occurs mostly in pods and veinlets in the chlorite breccia; chrysocolla and hematite occur in a 5-ft-thick shear zone in an upper pit in volcanic rocks.	Two small pits.	Two samples: both contained a trace of gold and silver, and 0.44 and 0.43 percent copper.
43	*Crescent mine (patented)	Most workings are situated in localized, intensely silicified, sericitized quartz monzodiorite and metasedimentary gneiss (Frost, 1980). Mineralized zones (faults and shears) range in thickness from 1.8 to 5.2 ft and contain one or more of the following: pyrite, limonite, earthy hematite, magnetite, chrysocolla, malachite, quartz, calcite, chalcedony, and antigorite. The main zone averages 2.9 ft thick and is exposed for approximately 275 ft along strike and for 70 ft down dip.	Four adits range in length from 10 to 135 ft, 2 inclined shafts, and 11 prospect pits. USBM records show 55 tons of ore, produced in 1917 and 1943, that contained 7 oz gold, 6 oz silver, and 8,615 lb copper.	Thirty samples: Twenty-one of 26 chip samples contained gold ranging from 0.0038 to 0.71 oz/ton; copper content ranged from 0.07 to 7.9 percent in 26 chip samples; silver content ranged from 0.014 to 0.4 oz/ton in 25 of the chip samples. Approximately 17,000 tons of identified (indicated inferred) resources containing an average of 0.14 oz/ton gold and 2.4 percent copper are estimated in the main zone. Because of the limited resources and high cost of underground mining, the resources are considered subeconomic at current (1986) prices of gold and copper.
44	*Venus prospect	Localized outcrops of quartz veins and felsic intrusive lenses are present in upper plate gneiss. A quartz outcrop is 0.5 to 0.7 ft thick, 50 ft long, strikes N. 50° W., and dips vertically. An aplite outcrop is 20 ft wide by 50 ft long and contains zones of gray, translucent quartz with limonite pseudomorphs after pyrite.	None.	Three samples: one sample of fractured granite contained 0.01 percent thorium.

45	*Copper Basin mine	A chalcopyite-, bornite-, and chalcocite-bearing porphyry-copper-type deposit capped by a secondary copper- and iron-bearing gossan (mostly malachite and limonite). The deposit may be related to an intrusion of adamellite into granite gneiss (Anderson and Frost, unpub. data, 1981).	Numerous shafts, adits, pits, drill pads, and buildings throughout the mine area.	Eighteen samples: Nine of 10 chip samples contained from 0.0007 to 0.11 percent copper; 8 other samples contained as much as 1.8 percent copper. From 7 to 11 million tons of 1 to 2 percent copper are estimated (Dravo Corp., 1974); these resources are located outside the study area and are currently (1986) subeconomic.
46	Copper Crest group (prospect)	Northwest-trending shear zone dips 34° to 83° SW. in gneiss. The zone ranges from 3.5 to 4.0 ft thick, contains limonite and chrysocolla with minor barite, and is discontinuously exposed for 0.5 mi.	Two pits, one 15-ft inclined adit, and two shafts 20 and 25 ft deep.	Three samples: two contained a trace and 0.042 oz/ton gold. The samples also contained 0.2, 0.6, and 1.4 oz/ton silver, and 0.22, 2.10, and 2.85 percent copper. Because of the encouraging length of the indicated structure and some favorable sample analyses, the prospect may warrant further investigation.
47	Outpost claim (prospect)	Northwest-trending altered shear zone dips southwesterly in gneiss and crystalline plutonic rocks. The zone ranges from 2.0 to 4.7 ft thick, contains chrysocolla and specular hematite and barite, and is intermittently exposed for about 1,000 ft. The zone is on strike with (and may be an extension of) a zone explored by prospect pits along the western edge of the Quadrangle Copper claim group.	Two shallow shafts.	Four samples: three contained a trace to 0.363 oz/ton gold and from 0.07 to 4.40 percent copper. Because of the favorable gold analyses in the samples, the prospect warrants further investigation.
48	*Quadrangle Copper group (prospect)	Geologically complex area consisting of metasedimentary gneiss and metagranite intruded by granitic rocks and felsic to mafic dikes. Abundant chrysocolla occurs in seams, pods, and veinlets parallel to, and in, fractures that are concordant to the northwest trend of roughly parallel listric faults that bound the area to the east and west.	Five shafts (mostly inclined), 4 adits, 3 trenches, and 28 prospect pits.	Twenty-nine samples: Nine of 31 chip samples contained between a trace and 0.35 oz/ton gold; most chip samples contained 0.2 to 0.6 oz/ton silver (2 contained 1.8 and 4.0 oz/ton); copper content ranged from 0.01 to 6.9 percent. Approximately 16,000 tons of subeconomic resources containing 2 percent copper are inferred in the larger of two structures on the property. Because of the length of the structure and favorable sample analyses, the property may warrant further investigation.
49	*Lortie group (prospect)	Most workings are located near a contact between mafic intrusive rocks, porphyritic granite, and gneiss. Sheared zones contain varying amounts of chrysocolla as fracture coatings, hematite, and jasper. Most volcanic rocks and altered (sericitic) gneissic rocks are chloritized.	Seven prospect pits and a shallow shaft on the main zone; one isolated prospect pit.	Five samples: three contained a trace of gold, two contained 0.007 and 0.174 oz/ton gold; silver ranged from 0.4 to 1.0 oz/ton (four samples); copper ranged from 0.30 to 3.90 percent.
50	*Peacock Copper group (prospect)	Chrysocolla occurs as fracture coatings in granite gneiss and an altered mafic intrusive body; an irregular barite-filled fracture zone is also in the gneiss. Most of the occurrences are moderately to heavily stained with hematite.	Two short adits, one prospect pit, and ruins of a loading ramp.	Three samples: two contained 0.018 and 0.045 oz/ton gold; three contained 0.2, 0.4, and 1.0 oz/ton silver; one sample had 0.43 percent copper and one contained 36.2 percent barite. The property may warrant further investigation because of favorable gold content in the two samples.
51	*Gold Crown group (prospect)	A shear zone in silicic to intermediate intrusive rocks contains chrysocolla, as fracture coatings, and abundant hematite stains.	One shallow inclined adit, three prospect pits, and ruins of a loading ramp.	One composite grab sample from the dumps contained 0.392 oz/ton gold and 2.17 percent copper. The property may warrant further study because of the gold content in the sample.

Table 2. Mines and prospects in the Whipple Mountains and Whipple Mountains Addition Wilderness Study Areas and vicinity, San Bernardino County, California—*Continued*

Map no. (fig. 3; pl. 1)	Name (commodity)	Summary	Workings and production	Sample and resource data
52	*Blue Heaven group (prospect)	Metasedimentary gneiss and metagranite is intruded by felsic to mafic dikes and granitic plugs(?). Chrysocolla and hematite occur as pods, stringers, and veinlets generally parallel to the northwest trend of listric faults in the area. The main zone is approximately 1,000 ft long.	Two major groups of workings totaling 10 adits, 10 shafts, 2 trenches, and 29 prospect pits. USBM files show 17 tons of ore, shipped from the Black Metal mine (at the northwest corner of the claim group) in 1941 and 1942; the ore contained 5 oz gold, 2 oz silver, and 1,366 lb copper.	Forty-five samples: Twenty-one of 38 chip samples contained from 0.006 to 1.56 oz/ton gold; 34 chip samples contained from 0.02 to 2.75 percent copper; 1 chip sample contained 0.7 oz/ton silver while others generally had from 0.2 to 0.4 oz/ton silver. Because of the large number of samples with favorable gold content, the property warrants further investigation.
53	*Blue Heaven Extension (prospect)	Scattered workings in plutonic, volcanic, and metamorphic rocks. Mineralized structures (generally shear zones) within and along contacts between dissimilar rock types contain chrysocolla and hematite, and in places barite.	Five pits, one trench, three short adits, one collapsed adit, and two inclined shafts.	Fifteen samples: gold ranged from a trace to 0.976 oz/ton in 10 samples, and averaged approximately 0.17 oz/ton; silver ranged from 0.2 to 0.6 oz/ton in 10 samples; copper ranged from 0.02 to 4.70 percent in 7 samples. Because of the number of samples with favorable gold content, the property warrants further investigation.
54	*Bonus group (prospect)	Chrysocolla and malachite occur in a gangue of hematite, quartz, and fault gouge in shears and faults of a quartzo-feldspathic gneiss. The prominent shear and fault zones, which range from 1 to 5 ft thick and have erratic lengths of exposure, strike northwesterly and dip to the southwest. Most contain chrysocolla and hematite.	One inclined shaft, seven adits and associated cuts total about 300 ft long; three prospect pits.	Fifteen samples: Six of 10 chip samples contained from 0.005 to 0.687 oz/ton gold; 9 chip samples contained from 0.12 to 1.6 percent copper; silver in all samples was greater than or equal to 0.6 oz/ton. The favorable gold content of some of the samples indicates the property may warrant further investigation.
55	*Klondike group (prospect)	Quartz blebs and fracture fillings occur in shear zones that strike northwesterly and dip to the southwest in quartzo-feldspathic gneiss intruded by mafic dikes. The shear zones contain limonite and hematite with occasional flecks of malachite and chrysocolla, and oxides of manganese. The zones trend northwesterly with the regional structural grain, are discontinuous along strike, and range from a few inches to 5 ft thick.	Three groups of workings total 5 adits, 12 shafts, and 13 prospect pits. USBM records show the Klondike Mine produced 99 tons of ore, intermittently between 1906 and 1941, that contained 43 oz gold and 13 oz silver.	Seventeen samples: three of nine chip samples contained 0.02, 0.06, and 0.53 oz/ton gold; eight chip samples contained between 0.03 and 0.52 percent copper; five of seven grab samples contained 0.006, 0.01, 0.228, 0.260, and 0.88 oz/ton gold. A few favorable gold analyses indicate the property may warrant further investigation.

Mineral Resources of Wilderness Study Areas: Eastern California Desert Conservation Area, California

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