UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

MINERAL-RESOURCE POTENTIAL OF THE WHIPPLE MOUNTAINS WILDERNESS STUDY AREA (CDCA-312) SAN BERNARDINO COUNTY, CALIFORNIA

by

Sherman P. Marsh[1], James Ridenour[2], Gary L. Raines[1], Keith A. Howard[1], Robert W. Simpson[1], Phillip R. Moyle[2], Spencee L. Willett[2], Donald P. Hoover[1]

OPEN FILE REPORT 82-956

1982

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

[1] U.S. Geological Survey
[2] U.S. Bureau of Mines

FOREWORD

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 Wilderness Study Area (CDCA-312), California Desert Conservation Area, San Bernardino County, California.

Whipple Mountains

Contents

ILLUSTRATIONS

TABLE

SUMMARY

The Whipple Mountains Wilderness Study Area (CDCA-312) has been evaluated by a multidisciplinary team of geoscientists, and the potential for several types of mineral resources classified using the McKelvey diagram: (1) A large area in the upper plate rocks of the Whipple Mountains detachment fault in the south and southwest part of the study area contains hypothetical resources for base and precious metals (copper, lead, and zinc with varying amounts of silver and molybdenum). Inferred resources for base and precious metals occur in and around the area of the Turk Silver mine and Lucky Green Group. (2) Base and precious metal mineralization in the lower plate rocks of the Whipple Mountains detachment fault appears to be structurally controlled and the resource potential ranges from identified marginal to speculative. (3) A small area on the southeastern margin of the study area in the lower plate of the Whipple Mountains detachment fault contains a small resource potential for indicated to speculative, base and precious metal mineralization that could be related to dislocated sections of a granite pluton. (4) Manganese occurs throughout the northern portion of the area in Tertiary volcanic rocks of the upper plate of the Whipple Mountain detachment fault. The manganese resources range from inferred to hypothetical. (5) The thick section of Tertiary lake bed sediments at the eastern margin of the study area contains a speculative resource potential for uranium. (6) A small quarry on the southern margin of the study area contains a measured resource for decorative stone. (7) Large quantities of sand and gravel are present, but are not considered as a resource because of their remote location and the availability of similar materials outside the wilderness area. (8) The potential for geothermal resources, placer gold, and oil and gas resources were also evaluated but no resources were identified.

INTRODUCTION

This report summarizes the results of a mineral survey of the Whipple Mountains Wilderness Study Area (CDCA-312) (fig. 1) conducted jointly by the U.S. Geological Survey and the U.S. Bureau of Mines; the area encompasses approximately 85,100 acres (34,400 ha) including enclosed private lands, in southwestern San Bernardino County, California (U.S. Department of the Interior, Bureau of Land Management, 1980, p. 557). The U.S. Geological Survey, using geological, geochemical, and geophysical techniques, investigated the study area to define the extent 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 U.S. Bureau of Mines studied, in detail, the mineral resources of mines and prospects in the study area and helped integrate this information with the U.S. Geological Survey studies. The defined areas of mineral-resource potential (fig. 3) were classified using the modified McKelvey diagram (fig. 4) (U.S. Bureau of Mines and U.S. Geological Survey, 1980), and these areas represent an evaluation as of 1981.

The Whipple Mountains Wilderness Study Area (CDCA-312) is located on the eastern edge of the Mojave Desert; the area lies 6 mi (10 km) northwest of Parker, Arizona and 10 mi (16 km) southwest of Lake Havasu City, Arizona, and encompasses a major portion of the Whipple Mountains. The study area is covered entirely by U.S. Geological Survey 7-1/2 minute series topographic quadrangle maps. The borders of the area are irregular and defined by the Chemehevi Indian Reservation and powerline road on the north and northeast and by an unimproved dirt road on the west. The southern and southeastern border is approximately one mile (1.6 km) north of the Colorado River aqueduct. Major

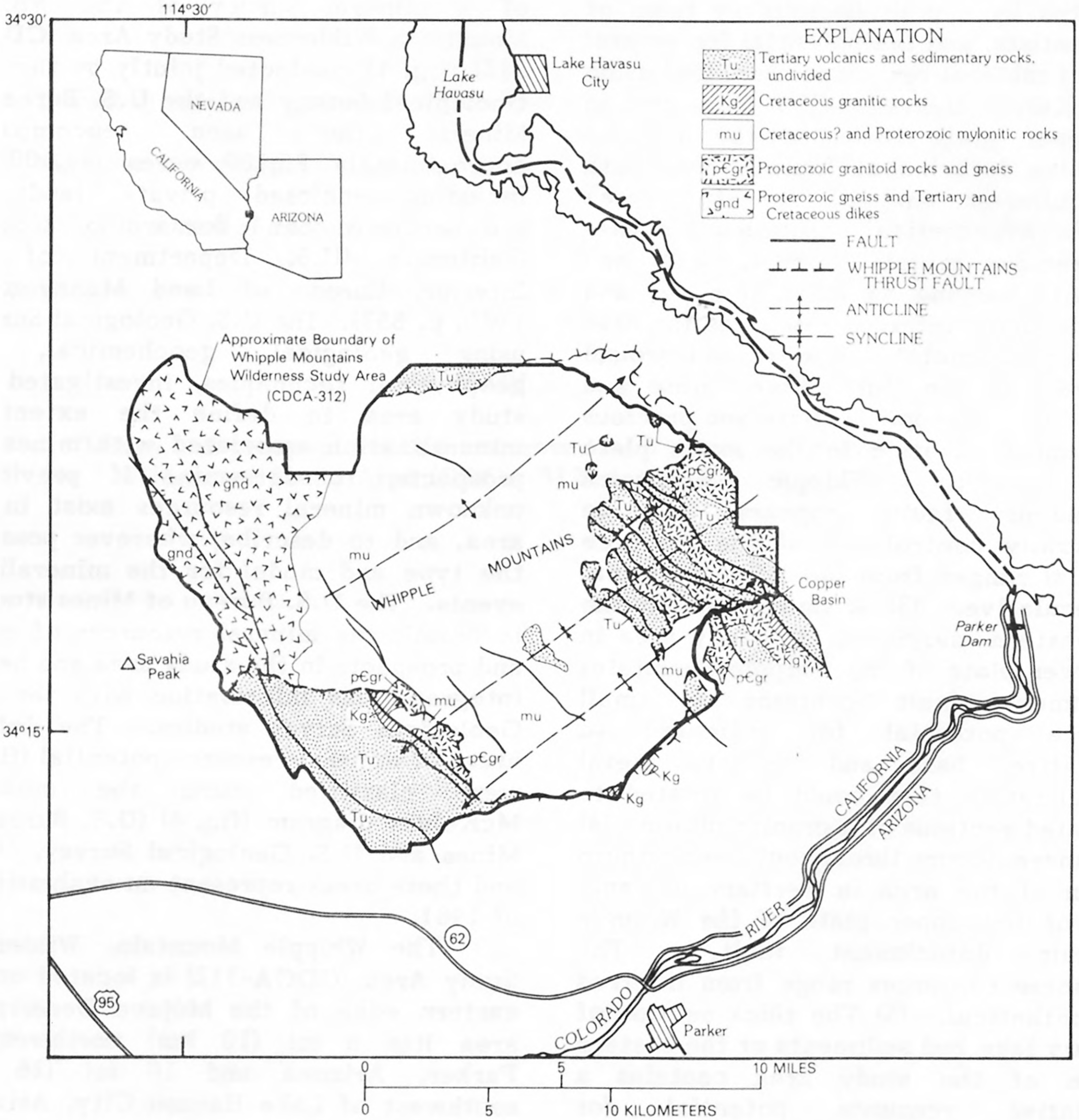


Figure 1.--Location map and generalized geology of the Whipple Mountains Wilderness Study Area (CDCA-312), San Bernardino County, California.

access to the area is from California State 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 1200 ft (365 m) along the southern border of the area to an elevation of 4131 ft (1260 m) 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 (155 m) from the canyon floor. The terrane is rugged with sloping flanks to the south and precipitous faces to the north.

Results from this investigation of the Whipple Mountains Wilderness Study Area (CDCA-312) are described in detail in a number of studies on the geology (Davis and others, 1982), geochemical surveys (Marsh, S. P. and Raines, G. L., unpub. data, 1982), remote sensing (Raines, 1982), gravity and magnetics (Simpson, R. W. and Gage, T. B., unpub. data 1982), geoelectrical surveys (Hoover, D. B., unpub. data 1982) and an investigation of mines and prospects (Ridenour, Moyle, and Willett, unpub. data, 1982).

ACKNOWLEDGMENTS

During the investigation of the mineral-resource potential of the Whipple Mountain Wilderness Study Area (CDCA-312), many disciplines of geologic science were employed. 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 Wilderness Study Area (CDCA-312). J. Lawford Anderson and Gregory A. Davis (University of Southern California), Eric G. Frost (San Diego State University), and Wilfred J. Carr (USGS) provided valuable insights to the detailed geology and structural problems of the Whipple Mountains. James K. Otton (USGS) 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.

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 basements overprinted by low-dipping mylonitic fabrics and overlain on decollements (detachments) 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, 1982a,b; Anderson and Frost, 1981; 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.

Rocks of the lower plate below the fault include Proterozoic metamorphic and plutonic rocks. Below and east of a mylonite front exposed in the west part of the study area, the Proterozoic rocks have a gently dipping mylonitic foliation associated with Cretaceous(?) granitic sheet intrusions (Davis and others, 1982a, b). Petrologic studies suggest that the granitic sheets were emplaced at depths exceeding 6 mi (9.6 km) (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 Cretaceous or Tertiary dikes of diabase to dacite composition in the dense Chambers Well dike swarm (Davis and others, 1982a, b; Carr, Dickey and Quinlivan, 1980).

The upper plate above the fault exposes crystalline rocks overlain by Tertiary volcanic and sedimentary strata (Davis and others, 1980, 1982b). 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 southeast of the study area, has been related to intrusion of nearby Cretaceous granite by Anderson and Frost (1981) based on like K-Ar ages of the granite and 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 (Davis and others, 1982b). 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 Pliocene age (Bouse Formation), and alluvial and fluvial deposits of Quaternary age (Dickey and others, 1980; Davis and others, 1980, 1982b; 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 (120 m). 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, 1982b). 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, 1982b).

Above the Whipple Mountains detachment fault, the upper plate is cut by a series of northeast-dipping normal faults which repeat the Tertiary section and underlying upper plate crystalline rocks over and over again (Davis and others, 1980, 1982b; Frost, 1980; Dickey and others, 1980). These faults join or bottom against the detachment fault. The upper plate blocks are rotated to southwestward 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 lower Miocene strata (Frost, 1979; Davis and others, 1980; 1982b). 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, 1982). The detachment fault defines gentle troughs and ridges which Frost (written commun., 1982) and Wilkins and Heidrich (1982) have suggested may partly control sites of ore deposition. Cameron and Frost (1981) and Davis and others (1982b) interpreted these troughs and ridges as folds.

Carr (1981) suggested that horizontal offset along the Whipple Mountains detachment fault probably exceeds 12 mi (20 km). 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 (30-40 km) 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 (12 km) 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 a few places, such as the western part of the study area (e.g. Dickey and others, 1980; Carr and others, 1981). Virtually undeformed and unmineralized rocks deposited unconformably across the deformed terrane demonstrate the end of most deformation before 13 m.y. ago (Dickey and others, 1980; Davis and others, 1980; Carr, 1981).

GEOCHEMISTRY

A reconnaissance geochemical study to assess the mineral resource potential of the Whipple Mountains Wilderness Study Area (CDCA-312) 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 from stream sediments, and rocks. Sediments and concentrates were collected from 154 drainages in the Whipple Mountains Wilderness Study Area (CDCA-312), each drainage representing a 1-2 sq mi (1.5-3 sq km) area. Selected samples were taken 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 -80 mesh (-177 μm) fraction of sediment and the nonmagnetic heavy (2.6 sp gr) 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. These data along with statistical data for the Whipple Mountains Wilderness Study Area (CDCA-312) are listed in Marsh and others (1982).

Semiquantitative spectrographic analyses of the nonmagnetic fraction of the panned concentrates from stream sediments proved to be the most useful in evaluating the Whipple Mountains Wilderness Study Area (CDCA-312). 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 relationship of limonite occurrences to hydrothermal alteration related to mineralization, we analyzed the intermediate magnetic fraction of the panned concentrates from stream sediments. This sample medium was used because it contained 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 contained anomalous concentrations of metals.

The regional geochemical survey in the Whipple Mountains Study Area (CDCA-312) delineated regions of mineralization, helped identify areas of hydrothermal alteration, and helped establish the relationship of mineralization to the Whipple Mountains detachment fault. In addition, the survey identified geochemical suites of elements characterizing the rocks in the Whipple Mountains.

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 defined by Blanchard (1968), as a general term for hydrous iron oxides, but modified to include any material with the unique spectral reflectance properties of the ferric oxide minerals such as hematite and goethite as defined by 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 believed to be insignificant. All areas defined as limonitic from the satellite analysis were visited and sampled selectively to determine if the limonite was associated with hydrothermal alteration or if so, with what type of alteration and (or) mineralization. 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.

GEOPHYSICS

Geophysical investigations were conducted by the U.S. Geological Survey as part of the multidisciplinary study of the Whipple Mountains Wilderness Study Area (CDCA-312). The work included aeromagnetics, gravity, vertical electrical soundings, and audio-magnetotelluric readings.

Aeromagnetics and Gravity

Regional aeromagnetic and Bouguer gravity maps both display large positive anomalies in the western portion of the Whipple Mountains Wilderness Study Area (CDCA-312) (Simpson, R. W. and Gage, T. B., unpub. data, 1982; U.S. Geological Survey, 1981; Chapman and Rietman, 1978). It is not clear what relation, if any, these high anomalies might have to mineralization, but mines and prospects do occur on the northern and western periphery of the anomalies.

The very highest total field magnetic values occur about 1 mi (1.7 km) south southeast of the War Eagle mine over a small outcrop area of gabbro. An arm of the magnetic high extends to the north north-east 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 diorite. The extent of the anomalies suggests occurrence of considerably more of these mafic materials at depth than are seen at the surface. Unfortunately, the age and relationship of these rocks to the lower plate gneisses are not known.

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 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 American Eagle and D and W mines 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 which have been inferred by Healey and Currey (1980) to mark a through-going fault. Mapped faults parallel to this trend also appear close by on the geologic compilation of W. J. Carr's mapping (Stone and Howard, 1979). Thus the presence of faults and dikes and intrusive rocks might possibly mark an area of potential mineralization.

On the northern periphery of the Whipple Mountains Wilderness Study Area (CDCA-312), there are fewer mines and prospects than occur on the west. As previously mentioned, the War Eagle mine lies just north of the highest portion of the magnetic high. The north-northeast-trending linear gradient which bounds this high on the northwest (about 0.6 mi or 1 km south southeast of the War Eagle mine) is again suggestive of structure control, as is a more diffuse north-northwest-trending magnetic gradient which passes through the location of the War Eagle mine. Again, the coincidence of structure and igneous rocks suggests possibilities for mineralization.

Geoelectrics

Within the study area four induced polarization (IP) survey lines were run in the vicinity of the D and W and New American Eagle mines (fig. 2 and table 1, nos. 9 and 4) and two in the vicinity of the War Eagle mine (fig. 2 and table 1, no. 2). These lines were run because the IP method provides a direct indication of polarizable minerals such as clays and metallic luster sulfides and thus can provide evidence for the possible extent of mineralization at depth in the vicinity of the mines. In addition to this, twelve Schlumberger vertical electrical soundings (VES), and three experimental audio-magnetotelluric (AMT) soundings were made. The electrical soundings 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 and W mines, IP work showed a southeast-trending polarizable zone at least 5000 ft (1600 m) 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 300 m 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 and W mine, but no polarizable body was observed near the mine. The main polarizable structure is located about 1900 ft (600 m) northeast of the D and W shaft.

At the War Eagle mine the IP data show a polarizable body similar to that observed at the New American Eagle. Values for the ability for polarization were slightly larger than observed near the American Eagle and the largest observed in the study area. The data suggest a broad, 320-ft (100 m), near-vertical zone of increased polarization extending to at least 1000 ft (300 m) 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 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 to some depth, suggests mineralization well within the lower plate here. It appears that further work is needed before an understanding is achieved of the source of mineralization.

Vertical electrical soundings (VES) within the lower plate showed near-surface resistivities of about 100 ohm-meters slowly increasing to about 1000 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 on the detachment surface of 20°.

MINES AND PROSPECTS

During the multidisciplinary study of the mineral-resource potential of the Whipple Mountain Wilderness Study Area (CDCA-312), the U.S. Bureau of Mines collected 643 hard rock samples, 56 placer samples, and 31 petrographic samples from the 50 mine and prospect localities shown on figure 2. Field investigations included a search for all known mines and prospects, guided by claim records, locations shown on existing maps, and notations in literature. Prospect sites were examined, sampled, and mapped where warranted. Chip samples were taken from mineralized structures or grab samples from dumps where entry to excavations was prohibited. These samples were fire assayed for gold and silver. At least one sample from each locality was analyzed by semiquantitative spectrographic methods; elements in anomalous concentrations were then analyzed by atomic absorption, colorimetric, or X-ray fluorescent quantitative methods. Petrographic examinations were performed to determine selected rock types, alteration suites, and mineral assemblages. Reconnaissance pan and channel samples

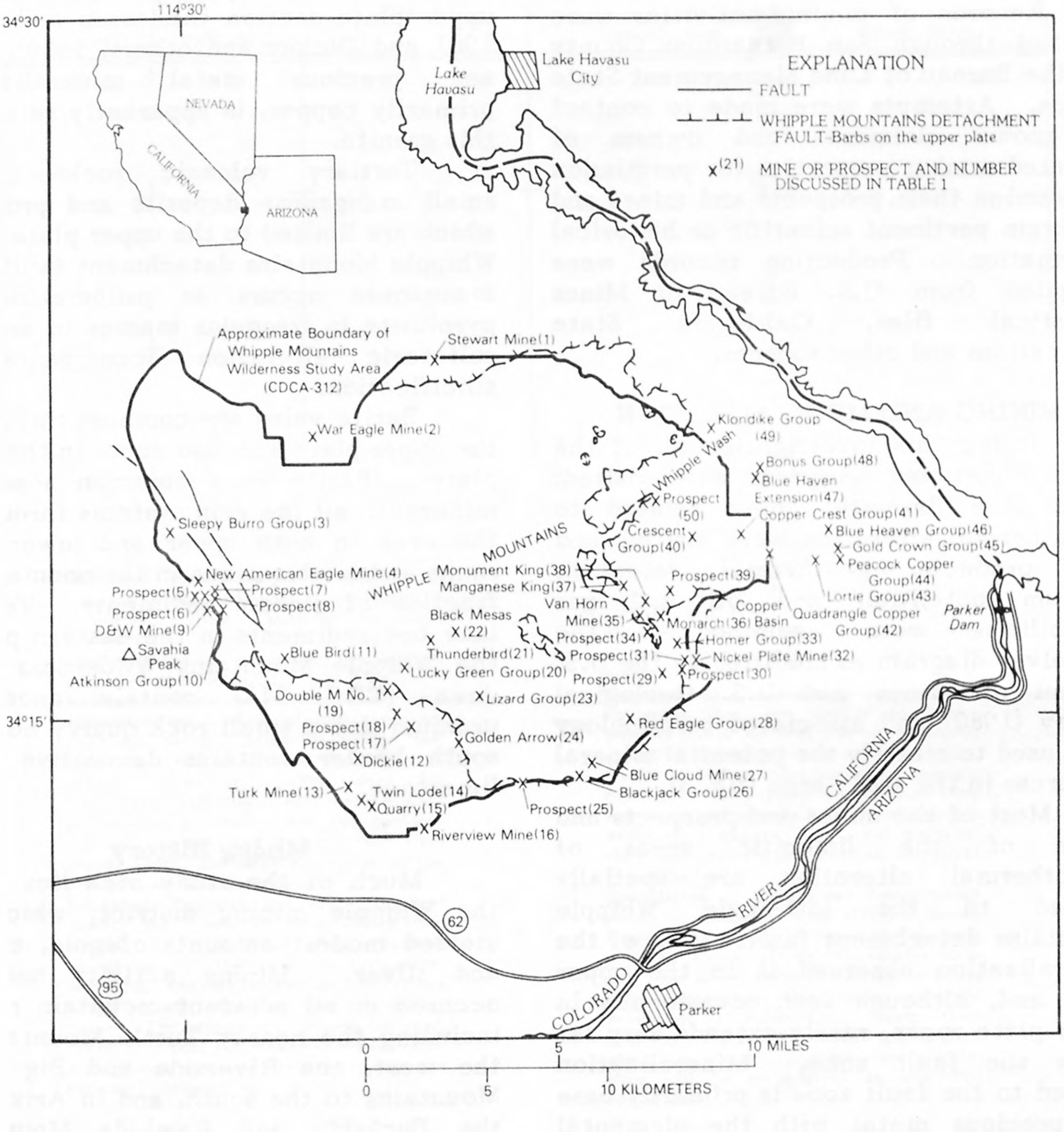


Figure 2.--Map showing mines and prospects within and near the Whipple Mountains Wilderness Study Area (CDCA-312), San Bernardino County, California.

of alluvium were analyzed. Selected heavy mineral fractions were checked for specific minerals.

Records of mining activities were checked through San Bernardino County and the Bureau of Land Management State Office. 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 pertinent scientific or historical information. Production records were compiled from U.S. Bureau of Mines statistical files, California State publications and other sources.

MINING AND MINERALIZATION

During this investigation all of the known mines and prospects were visited; all of the limonitic zones related to hydrothermal alteration were visited; and rock products, geothermal potential, uranium potential, and oil and gas possibilities were examined. The McKelvey diagram as modified by the U.S. Bureau of Mines and U.S. Geological Survey (1980) and associated terminology were used to classify the potential mineral resources in the study area (fig. 3).

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 occasionally in lower plate rocks, rarely extends very far below the fault zone. Mineralization related to the fault zone is primarily base and precious metal 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, 1982) resulting from dislocation of upper plate rocks. The observed minerals are oxides and carbonates with rare sulfides.

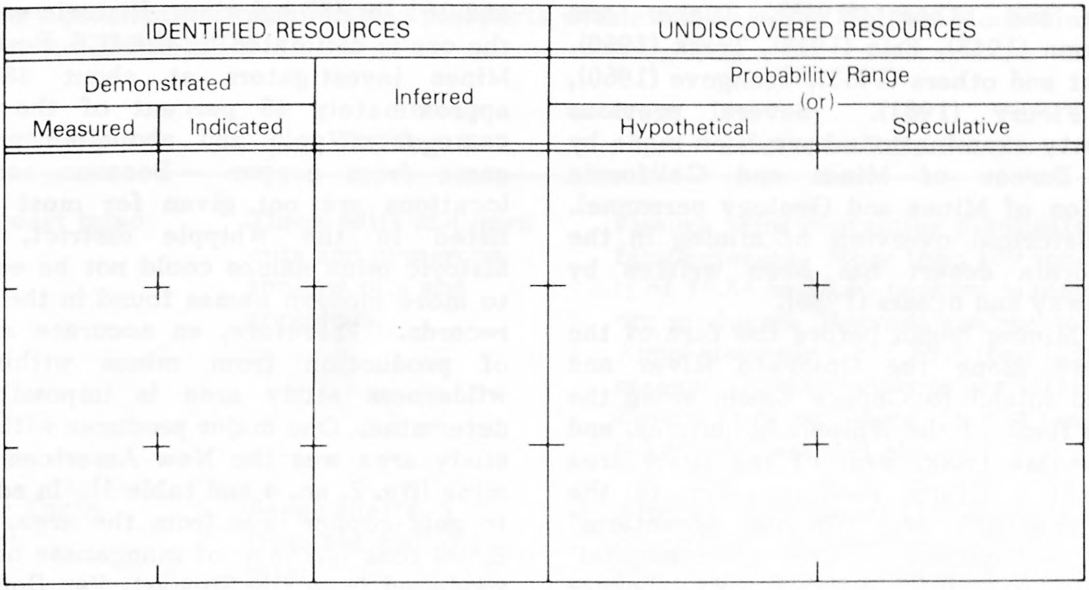
Along the southeastern margin of the area, in upper plate rocks, one or several Cretaceous granite bodies have been dislocated by northwest striking normal faults that repeat much of the upper plate section (Anderson and Frost, 1981 and Dickey and others, 1980). Base and precious metal mineralization, primarily copper, is apparently related to this granite.

Tertiary volcanic rocks contain small manganese deposits and prospects which are limited to the upper plate of the Whipple Mountains detachment fault. 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 and is ubiquitous in the nonmagnetic fraction of stream sediments. Tertiary lake bed sediments in the eastern part of the Whipple Mountains Wilderness Study Area (CDCA-312) contain anomalous uranium and a small rock quarry near the south border contains decorative sandy limestone.

Mining History

Much of the study area lies within the Whipple mining district, which has yielded modest amounts of gold, copper, and silver. Mining activity has also occured in all adjacent mountain ranges, including the nearby Turtle Mountains to the west, the Riverside and Big Maria Mountains to the south, and in Arizona in the Buckskin and Rawhide Mountains. Early mining activity in the Whipple district has been recorded by Root (1909), Bancroft (1911), and Jones (1920). Specific descriptions or notations of various mines, prospects, and mineralized areas within the Whipple district are given by Bailey (1902), Turner (1907), Aubury (1908), Graeff (1910), Stevens (1911), Cloudman and others (1919), Tucker (1921), Tucker and Sampson (1930, 1931),



Identified Resources.--Resources whose location, grade, and quantity are known or estimated from specific geologic evidence.

Demonstrated.--A term for the sum of measured plus indicated.

Measured.--Quantity is computed from dimensions revealed in outcrops, trenches, workings, or drill holes: grade and (or) quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurement are spaced so closely and the geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established.

Indicated.--Quantity and grade and (or) quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurement are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation.

Inferred.--Estimates are based on an assumed continuity beyond measured and (or) indicated resources, for which there is geologic evidence. Inferred resources may or may not be supported by samples or measurements.

Hypothetical Resources.--Undiscovered resources that are similar to known mineral bodies and that may be reasonably expected to exist in the same producing distict or region under analogous geologic conditions. If exploration confirms their existence and reveals enough information about their quality, grade, and quantity, they will be reclassified as identified resources.

Speculative Resources.--Undiscovered resources that may occur either in known types of deposits in favorable geologic settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential. If exploration confirms their existence and reveals enough information about their quantity, grade, and quality, they will be reclassified as identified resources.

Figure 3.--Classification of mineral resources for the Whipple Mountains Wilderness Study Area (CDCA-312), San Bernardino County, California (modified from U.S. Bureau of Mines and U.S. Geological Survey, 1980).

Trask and others (1943), Tucker and Sampson (1943), Eric (1948), Trask (1950), Wright and others (1953), Trengove (1960), and Fleury (1961). Several previous property examinations have been made by U.S. Bureau of Mines and California Division of Mines and Geology personnel. An historical overview of mining in the California desert has been written by Shumway and others (1980).

Mining began before the turn of the century along the Colorado River and spread inland to Copper Basin, along the south flank of the Whipple Mountains, and to Savahia Peak, west of the study area (fig. 1). Claim records refer to the "Monumental" or "Whipple Mountains" mining districts. The "Monumental" district probably encompassed Copper Basin, most of which lies outside the eastern border of the study area. The rest of the study area lies within the Whipple district which also includes mines and prospects in the vicinity of Savahia Peak, approximately 3 mi (4.8 km) west of the study area. More than 5,000 claims are estimated to have been filed in and around the study area since the late 1800's; 8 lode claims have been patented. A record search revealed no placer claims in the vicinity of the Whipple Mountains Wilderness Study Area (CDCA-312). Bureau of Land Management records indicate approximately 165 active lode claims within the study area as of February 1981.

U.S. Bureau of Mines statistical files show 5,123 tons (4,648 t) of ore have been produced from 56 mines in the Whipple district, exclusive of Copper Basin, beginning in 1906 and ending in 1969. The ore contained 1,332 oz (41,429 g) gold, 9,436 oz (293,488 g) silver, 181,486 lbs (82,322 kg) copper, 1,192 lbs (541 kg) lead, and 181 lbs (82 kg) zinc. Historic value of the ore is estimated by the U.S. Bureau of Mines investigators at about $84,000; approximately 48 percent of the value came from gold and about 45 percent came from copper. Because accurate locations are not given for most mines listed in the Whipple district, many historic mine names could not be equated to more modern names found in the claim records. Therefore, an accurate amount of production from mines within the wilderness study area is impossible to determine. One major producer within the study area was the New American Eagle mine (fig. 2, no. 4 and table 1). In addition to gold-copper ores from the area, about 2,500 tons (2,268 t) of manganese ore was produced from the Stewart, Van Horn, and Monarch-Manganese King-Monument King mines (fig. 2, nos. 1, 35, 36, 37, and 38 and table 1), between World War I and the 1950's. Value of the manganese ore is unknown. Considerable handsorting was necessary to make the minimum acceptable grade. Production of manganese ore during World War II and the 1950's was probably in response to government stockpiling programs.

Much of the mining activity in the Whipple Mountains Wilderness Study Area (CDCA-312) has been limited to intermittent extraction of relatively small, high-grade pockets of mineralized rock. Prospecting targets were podiform to lensoid chrysocolla and hematite occurrences in fracture zones. Underground mining was accomplished largely through sinking shafts and subsequent drifting on "ledges" of mineralized rock. Production records indicate this activity was most prevalent prior to World War I and from the depression years through World War II.

Table 1.--Summary descriptions of mines and prospects within and near the Whipple Mountains Study Area (CDCA-312).

Map. No. (fig. 2)	Name	Workings	Resource Data
1	Stewart mine	Three adits and open cuts and numerous shallow pits and scrapings.	Fissure veins containing pyrolusite in fanglomerate. More than 100 tons (91 t) of 35.84 to 39.66 percent manganese ore produced. Records are not complete. Approximately 2,575 long tons (2343 t) of manganiferous resources are inferred. Eleven samples taken: results ranged from 6.0 to 64.0 percent Mn.
2	War Eagle mine	Seven shafts, 5 trenches and 11 pits.	Altered and mineralized shears and basaltic dikes, rhyolite and andesite. Minor production of silver and copper ore but amounts unknown. Twenty-five samples taken: one contained detectable gold and three others minor silver. Thirteen contained copper in the range of 0.01 to 0.17 percent.
3	Sleepy Burro Group	Eight shafts, one adit and numerous pits.	Schist and gneiss cut by chrysocolla-malachite- and chalcopyrite-bearing porphyritic dikes. Minor gold-copper-silver production. Twenty five samples taken: one contained 0.45 oz gold/ton (15 g gold/t). Three have 0.02 to 0.12 oz gold/ton (0.7 to 4 g gold/t). Silver values ranged from nil to 0.4 oz/ton (nil to 14 g silver/t). Copper values ranged from nil to 6.2 percent. Nine had more than 1.0 percent copper.
4	New American Eagle mine	Two shafts, several cuts and shallow pits, and concrete millsite foundation.	NW-trending fault zone in gneiss and metarhyolite intruded by porphyritic dikes. More than 700 tons (640 t) of ore produced averaged about 8 percent copper. The ore contained some gold and silver. Eric (1948, p. 298) reported "reserves of 90,000 tons of 3.8 percent Cu." Six samples taken: samples had 0.90 to 2.9 percent copper, nil to 0.44 oz gold/ton (35 g gold/t) and nil to 1.4 oz silver/ton (nil to 47 g silver/t).

Table 1.--Summary descriptions of mines and prospects within and near the Whipple Mountains Study Area (CDCA-312). (continued)

Map. No. (fig. 2)	Name	Workings	Resource Data
5	Prospect	Four shallow pits.	Altered shear zone in gneiss. Three samples taken: two contained no gold or silver and 0.01 and 0.27 percent copper. One sample contained 0.5 oz gold and 0.4 oz silver/ton (17 g gold and 14 g silver/t) and 0.91 percent copper.
6	Prospect	One adit.	Shear zone in felsite. One sample: no gold, 20 oz silver/ton (681 g silver/t), and 0.91 percent copper.
7	Prospect	One shallow shaft.	Altered zone adjacent to shear in gneiss. One sample: no gold or silver detected and 0.01 percent copper.
8	Prospect	One pit.	Chrysocolla-stained mafic dike in granitic gneiss. One sample: no gold or silver and 1.70 percent copper.
9	D & W mine	One shaft, an adit and several small pits.	Felsite intruded by mafic sills. Ore deposits at depth are associated with a quartz porphyry dike in gneiss (Wright and others, 1953). Seventy-five tons of ore shipped: one shipment contained 7.98 oz (247 g) gold and 2 oz (62 g) silver. Thirteen samples taken: one sample contained 1.03 oz gold/ton (44 g gold/t), the other had nil to 0.16 oz gold/ton (nil to 5.5 g silver/t). Silver ranged from nil to 0.04 oz/ton (nil to 1.4 g/t) and copper 0.01 to 5.2 percent.
10	Atkinson Group (pat.)	Three shafts and 8 pits.	Gneiss and metarhyolite intruded by mafic dikes. Seven samples: one had 0.18 oz gold/ton (6 g gold/t); silver ranges from nil to 1.0 oz/ton (nil to 31 g/t) and copper from 1.30 to 6.95 percent.
11	Blue Bird mine	One adit, 1 shaft and numerous pits and dozer cuts.	Chrysocolla and hematite as fracture coating in mylonitic gneiss. Thirteen samples: nil to 0.04 oz gold/ton (nil to 1.4 g gold/t); 0.2 to 0.8 oz silver/ton (7 to 27 g silver/t); 0.2 to 5.4 percent copper.

Table 1.--Summary description of mines and prospects within and near the Whipple Mountains Study Area (CDCA-312). (continued)

Map. No. (fig. 2)	Name	Workings	Resource Data
12	Dickie Claim	One shaft and 1 pit.	Veinlet of chrysocolla in gneiss. Two samples: no gold detected; 0.2 and 0.3 oz silver/ton (7 and 10 g silver/t) and 33.2 and 6.5 percent copper.
13	Turk Silver mine	Three shafts, 2 adits and 19 pits.	Fault breccia zone between sedimentary and volcanic rocks. Approximately 1957 tons of silver-bearing resources are inferred. Twenty seven samples taken: one contained 0.02 oz gold/ton (0.7 g gold/t), the others a trace. Silver values ranged from a trace to 8.6 oz/ton (293 g silver/t); 22 samples contained greater than 0.01 to 0.09 percent copper and 5 samples had 0.20 to 3.50 percent copper.
14	Twin Lode	Two adits, 1 trench and 4 pits.	Sedimentary rocks in fault contact with volcaniclastics. Eleven samples: samples averaged about 7 oz silver/ton (239 g silver/t) and 0.10 percent copper.
15	Decorative stone property	One small quarry.	Flat-lying, thin-bedded sandy limestone with visible cherty layers. An inferred resource of 1008 tons (98 t) of building stone.
16	Riverview mine	Four adits, 7 shafts, 13 trenches and 26 pits.	Granitic gneiss in fault contact with andesite. Tucker and Sampson (1943) report a total of 200 tons (180 t) of ore shipped averaging 3.82 percent copper and $12.12/ton gold. Moderate production was reported during the years 1938, 1939, 1941, 1944, 1952, and 1956. Eighty-seven samples taken: copper, found in 74 samples ranged from 0.01 to 4.40 percent with 9 above 1.0 percent. Silver, detected in 18 samples ranged from 0.2 to 0.4 oz/ton (7 g to 14 g silver/t) for all except one which contained 16 oz/ton (469 g/t). Gold ranged from 0.01 to 0.42 oz/ton (0.3 to 14.3 g/t), averaging 0.06 oz/ton (2 g/t).

Table 1.--Summary description of mines and prospects within and near the Whipple Mountains Study Area (CDCA-312). (continued)

Map. No. (fig. 2)	Name	Workings	Resource Data
17	Prospect	One shaft, 1 pit and several bulldozer cuts.	Chloritic breccia shear in gneiss(?) Two samples: trace gold; trace to 1.6 oz silver/ton (trace to 55 g silver/t); 0.04 and 1.3 percent copper.
18	Prospect	One pit.	Iron-oxide stained breccia zone in gneiss? One sample; no gold, silver or copper detected.
19	Double M No. 1 Claim	Three trenches and 2 pits.	Three chloritic shears in gneiss. Three samples: one contained 0.2 oz silver/ton (7 g silver/t); no other silver, gold or copper detected.
20	Lucky Green Group	Four large open cuts with several smaller cuts, 2 short adits, numerous drill holes and leach vats.	Gneiss intridued by an adamellite plug. Approximately 1940 tons (1765 t) of copper-bearing resources are inferred. Twenty-three samples, no gold detected; silver content ranged from nil to 0.8 oz/ton (nil to 27 g/t); copper content ranged from 0.01 to 7.5 percent.
21	Thunderbird Group	Two shafts and 1 adit.	Sheared intrusive volcanic. Six samples: no gold detected; five contained 0.[illegible] to 0.4 oz silver/ton (7 to 14 g silver/t); copper ranged from 0.28 to 1.3 percent.
22	Black Mesas Claim	Two adits.	Breccia shear zone gneiss. Four samples: three contained 0.01 to 0.11 oz gold/ton (0.3 to 3.7 g gold/t); silver ranged from 0.4 to 1.4 (avg. 0.07) oz/ton (14 to 48 (avg. 24) g/t); three contained copper from 0.07 to 0.77 percent.
23	Lizard Group	Six shafts, 1 adit and several pits and	Northeast-trending mineralized zone in gneiss. Twenty one samples: no gold detected; seven samples contained 0.2 to 0.4 oz silver/ton (7 to 14 g silver/t); nineteen samples contained 0.02 to 10 percent copper

Table 1.--Summary description of mines and prospects within and near the Whipple Mountains Study Area (CDCA-312). (continued)

Map. No. (fig. 2)	Name	Workings	Resource Data
24	Golden Arrow Group	One shaft and 2 pits.	Chloritic shear zone in gneiss. Six samples: three contained from 0.01 to 0.03 oz gold/ton (0.3 to 1 g gold/t); 0.2 to 0.4 oz silver/ton (7 to 14 g silver/t), five samples contained from 0.10 to 0.66 percent copper.
25	Prospect	Two shafts, an adit and trench.	Vein of chrysocolla along detachment fault in metamorphics. Two samples: no gold detected; 0.2 to 0.3 oz silver/ton (7 to 10 g silver/t); 1.1 and 5.1 percent copper.
26	Blackjack Group	Nine pits and a bulldozed area.	Fault zone and fractured zone in gneiss. Eight samples: no gold detected; 0.04 to 0.65 percent copper; 7 samples had 0.07 to 3.49 percent barium.
27	Blue Cloud mine	Two shafts, 5 adits, 2 trenches, 10 pits, hoist, foundations and powder bunker.	Hydrothermally mineralized and altered shear zone in mylonitized gneiss. Three tons of ore produced. Total identified resources are 235,000 tons (214,000 t) containing 0.48 percent copper. Fifty samples taken: gold was detected in three and silver in nine. Copper ranged from 0.09 to 3.25 percent.
28	Red Eagle Group	Two shafts, 2 adits and 2 pits.	Sheared and faulted mylonitic gneiss. Eleven samples: nil to 0.02 oz gold/ton (0.7 g gold/t); as much as 0.4 oz silver/ton (14 g silver/t); copper ranges from 0.15 to 1.7 percent.
29	Prospect	One shaft and 5 pits.	Altered shear zones in chloritic gneiss. Five samples: all contained trace gold; silver ranged from trace to 0.4 oz/ton (trace to 14 g/t), and copper from trace to 2.1 percent.
30	Prospect	One shaft and 1 adit.	Shear zone in chloritic gneiss. Three samples: no gold or silver detected, 0.69 percent copper.
31	Prospect	One shaft.	Shear zone in chloritic gneiss. One sample: no gold or silver detected, 0.69 percent copper.

Table 1.--Summary description of mines and prospects within and near the Whipple Mountains Study Area (CDCA-312). (continued)

Map. No. (fig. 2)	Name	Workings	Resource Data
32	Nickel Plate mine	Four shafts, 2 adits, and 3 cuts.	Highly fractured and altered quartz monzonite in fault contact with volcanic and sedimentary rocks. About $7,700 worth of gold, silver and copper were produced. Approximately 1270 tons (1160 t) of indicated resource averaging 0.02 oz gold/ton (0.7 g gold/t) and 1.9 percent copper and 1525 tons (1390 t) averaging 0.02 oz gold/ton (0.7 g gold/t) and 1.0 percent copper. Twenty two samples: Ten samples contained gold ranging from 0.02 to 0.08 oz/ton (0.7 to 2.7 g/t); six had detectable silver; copper ranged from 0.10 to 5.00 percent.
33	Homer Group	Two pits.	Sheared altered chloritic gneiss. One sample: trace gold and silver and 0.5 percent copper.
34	Prospect	One pit.	Chlorite breccia along fault contact between upper and lower plate gneissic rocks. One sample: trace gold, 0.2 oz silver/ton (7 g silver/t) and 1.95 percent copper.
35	Van Horn mine	One adit with 3 stopes to surface, headframe and numerous pits.	Bedding plane fault in limestone. More than 700 tons (640 t) of ore with a manganese content ranging from 25 to 45 percent were produced. Nineteen samples: manganese ranged from 0.06 to 33.7 percent.
36, 37 and 38	Monarch, Manganese King, Monument King mines	Eight adits, 6 trenches, 18 pits.	Pods and lenses of manganese minerals roughly parallel to bedding in lime stone and volcanics. Production data are conflicting. Trengove (1960) reported total production for the Monarch as 1100 tons (1000 t) and greater than 600 tons (550 t) for the Monument King-Manganese King mines. Twenty-five samples: manganese ranged from 0.03 to 22.8 percent with an average of about 2.5 percent. Iron ranged from 0.80 to 44 percent.

able 1.--Summary description of mines and prospects within and near the Whipple Mountains Study Area (CDCA-312). (continued)

lap. No. ig. 2)	Name	Workings	Resource Data
39	Prospect	Two shafts.	Chlorite breccia at contact between upper and lower plate gneissic rocks. One sample: 0.6 oz gold/ton (20 g gold/t), no silver and 0.35 percent copper.
40	Crescent Group (pat.)		Permission to examine property was not granted by the owner.
41	Copper Crest Group	Two shafts, 1 adit and 2 pits.	Altered shear zones in gneissic country rock. Three samples: two contained trace and 0.042 oz gold/ton (1.4 g gold/t); silver 0.2, 0.5 and 1.4 oz/ton (7, 17, and 48 g/t); copper ranged from 0.22 to 2.85 percent.
42	Quadrangle Copper Group and Outpost Claim	Seven shafts, 4 adits, 3 trenches, and 28 pits.	Minerals occur along localized shears, dikes and contacts in metasediments and metagranitics. Approximately 16,000 tons (14,500 t) of ore averaging 2.0 percent copper are inferred. Thirty-three samples: ten contained trace to 0.363 oz gold/ton (12.4 g gold/t); silver was detected in nearly all samples but only three contained more than 1 oz (31 g). Copper ranged from 0.01 to 6.9 percent.
43	Lortie Group	One shaft and 8 pits.	Sheared zones along contact between mafic intrusive porphyritic granite and gneiss. Five samples: Three contained a trace of gold, two contained 0.007 and 0.174 oz gold/ton (0.2 and 5.9 g gold/t); silver values ranged from 0.4 to 1.0 oz/ton (14 to 31 g/t); copper ranged from 0.30 to 3.90 percent.
44	Peacock Copper Group	Two adits and 1 pit.	Fracture zone in gneiss and granitic gneiss and altered mafic intrusive. Three samples: trace, 0.018 and 0.045 oz gold/ton (trace, 0.61 and 1.53 g gold/t); 0.2, 0.4 and 1.0 oz silver/ton (7, 14, and 31 g silver/t); one sample yielded 0.43 percent copper and one sample contained 36.2 percent barite.
45	Golden Crown Group	One shaft, and 3 pits.	Shear zone in silicic to intermediate intrusive rocks. One sample: 0.392 oz gold/ton (13.4 g gold/t), 2.17 percent copper.

Table 1.--Summary description of mines and prospects within and near the Whipple Mountains Study Area (CDCA-312). (continued)

Map. No. (fig. 2)	Name	Workings	Resource Data
46	Blue Heaven Group	Nine shafts, 9 adits, 1 trench and 29 pits.	Minerals occur along localized shears, dikes, and contacts in metasediments and metagranitics. Some reported production. Forty-five samples: four contained 0.132 to 0.212 oz gold/ton (4.5 to 7.2 g gold/t) and three samples 0.593, 0.610 and 1.56 oz gold/ton (20.2, 20.7, and 53.1 g gold/t); three had more than 1 oz silver/ton (31 g silver/t), i.e., 9.0, 12.2 and 18.7 oz (279, 378.2, and 579.7 g); copper ranged from nil to 7.73 percent.
47	Blue Heaven Extension	Two shafts, 4 adits, 1 trench, and 5 pits.	Sheared contacts and faults in plutonics, volcanics and metamorphics. Fifteen samples: gold ranged from trace to 0.976 oz/ton (trace to 33.2 g/t) in ten samples (averaging 0.17 oz/ton (5.8 g/t); Silver from 0.2 to 0.6 oz/ton (7 to 20 g/t) in ten samples; copper ranged from 0.02 to 4.7 percent.
48	Bonus Group	One shaft, 7 adits, and 3 pits.	Highly brecciated and sheared zone in gneiss. Fifteen samples: gold ranged from 0.124 to 0.687 oz/ton (4.2 to 23.4 g/t) in six samples; (averaging 0.279 oz/ton (9.5 g/t)); silver from nil to 0.6 oz /ton (nil to 20 g/t); copper ranged form trace to 8.10 percent.
49	Klondike Group	One shaft, 5 adits, and 13 pits.	Volcanic rocks in fault contact with gneiss and sheared zone in gneiss. Ninety-nine tons of ore produced. Sixteen samples: four contained from 0.228 to 0.88 oz gold/ton (7.8 to 30 g gold/t); silver values ranged from nil to 0.6 oz/ton (nil to 20 g/t); copper ranged from 0.03 to 0.52 percent.
50	Prospect	Two pits.	Chloritic breccia in contact with volcanic breccia. Two samples: trace gold, trace silver; 0.43 and 0.44 percent copper.

RESOURCE EVALUATION

Placer Gold

Fifty-six reconnaissance and channel placer samples were collected during this investigation. Twenty-one were reconnaissance pan samples of modern alluvium from selected major washes or drainages in the Whipple Mountains. Calculated gold values of these samples ranged from nil to $1.03 per cubic yard[1] ($0.79 m^3). Thirty-five channel samples of Quaternary(?) alluvium taken mostly from the remains of a deposit in Whipple Wash in the NW1/4 SE1/4 sec. 19, T. 3 N., R. 26 E., ranged from nil to $.38 gold per cubic yard ($.29/$m^3$).

Factors which prohibit economic recovery of placer gold in the study area are: (1) most of the gold is very fine grained (minus 40-90 μm) with approximately half of the particles being flour gold (extremely fine or minus 200-440 μm), (2) lack of water for placer operations, and (3) the wash-type deposition of the alluvium is not conducive to concentration of gold at the alluvium-bedrock interface as often occurs in point bars and longitudinal bars of perennial streams. The commonly catastrophic nature of deposition does, however, result in thin, sheet-like rough concentrations of heavy minerals.

Base and Precious-Metal Mineralization Related to the Whipple Mountains Detachment Fault

The most visible mineralization in the Whipple Mountains is the ubiquitous, structurally controlled occurrence of upper silicate (chrysocolla) related to the Whipple Mountains detachment fault. The chrysocolla occurs in rocks from lower plate mylonitic and non-mylonitic assemblages to the upper plate Tertiary section, and ranges from thin coatings to massive, podiform to lensoid occurrences rarely more than a few inches thick. Lateral extent of these is often limited to a few inches, but several such occurrences are possible along any given fracture system. The chrysocolla is usually accompanied by earthy hematite, quartz, specular hematite, limonite, calcite, barite, chlorite, epidote, and sericite, although not all are present in any one occurrence. Generally speaking, barite and calcite associated with the chrysocolla are more prevalent in upper plate rocks. Alteration associated with the deposits is a chlorite-dominated propylitic assemblage, although quartz-sericite alteration was also observed. Immediately below the detachment fault lies an altered and highly disturbed zone called the chlorite breccia zone (Frost, 1980). Chlorite tends to be concentrated in and near this zone and appears to diminish in overall content upward in the structural section. The sulfide mineral assemblage appears to be confined to pyrite and chalcopyrite; these are found as disseminations in the chlorite breccia zone and as veinlets and blebs in mylonitic gneiss. Disseminated pyrite and chalcopyrite have been reported in drill logs in the upper plate crystalline suite at Copper Basin, just east of the wilderness study area boundary. Associated with the chrysocolla-hematite assemblage are low-grade copper-gold-silver values. Whereas copper is nearly always present, gold and silver values are spotty.

Structural analysis of fractures associated with areas of mineralization indicates distinct populations above and below the detachment fault that appear to be the result of crustal lengthening in the lower plate and dislocation in the upper plate. Two hundred and eighty-six attitude observations of mineralized structures were separated into lower and upper plate populations and analyzed by

---

[1] Price of gold $320 per troy oz as of June 1982.

computer. A concentration of poles in the lower plate were oriented N. 26° W., 48° NE. and a concentration of poles 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 confirm the suspected structural control of these occurrences by northeast-dipping listric and sympathetic normal faults and southwest-dipping antithetic and bedding plane faults. The dominant lower plate structural grain is within limits predictable for tension fractures resulting from the N. 50±10° E. direction of crustal extension and direction of movement of the upper plate. The minimum age limit for these mineral occurrences is believed to be mid-Miocene and the maximum limit is thought to be early in the dislocation process, late Oligocene, suggested by a 24.5 ± 0.7 m.y. K-Ar date of sericite. Collectively, these data indicate a temporal relationship between mineralization and dislocation in the Whipple Mountains Wilderness Study Area (CDCA-312) (Ridenour and others, 1982).

Mineralization in the upper plate of the Whipple Mountains detachment fault.--The upper plate of the Whipple Mountains detachment fault is lithologically varied and contains Precambrian 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, 1982a, 1982b). Mineralization occurs in this disturbed upper plate in listric normal faults, shear zones, and tension gashes.

Area A-1, Base and Precious Metals.--Two areas of upper plate rocks were identified as having potential for base and precious metal deposits (fig. 4): (1) A large area in the south-southwest portion of the wilderness study area and (2) a smaller area on the west side of the study area.

Geochemical sampling of stream sediments and panned concentrates from stream sediments was done throughout these areas and analyses of these sample media revealed that the southern area of upper plate rocks 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. Elemental anomalies in the 90th percentile or above resulting from the semiquantitative spectrographic analyses of nonmagnetic panned concentrates from stream sediments gave a trace element suite related to base metal mineralization. This suite consisted of copper greater than or equal to 100 ppm (parts per million) and lead greater than or equal to 200 ppm, with varying amounts of molybdenum (10-50 ppm) and silver (3 ppm). Barium was ubiquitous throughout the area; most samples contain more than 0.5 percent and reflect the many barite veins seen in the field. The base metal anomalies are strongest from areas that drain known mines and mineralization, but all samples in the area reflect the base metal suite. Four zones of limonitic material were defined in the area, and visits to these zones revealed that they were areas of propylitic alteration, structural complexity, and were, by and large, areas of previous mining activity. The intermediate magnetic fraction of panned concentrates from stream sediments draining these areas was analyzed by induction coupled plasma spectrographic methods (Church, 1981; Church and others, 1982), and the results from this sample medium revealed that along with anomalies in the base metal suite of elements there also were anomalies in arsenic ranging from 30 to over 400 ppm. Spectrographic analyses of rock samples from the Bluebird claims in the northwesternmost part of the propylitic (limonitic) zone (fig. 2 and table 1, no. 11) also identified anomalies in the base metal suite and in silver (5-20 ppm),

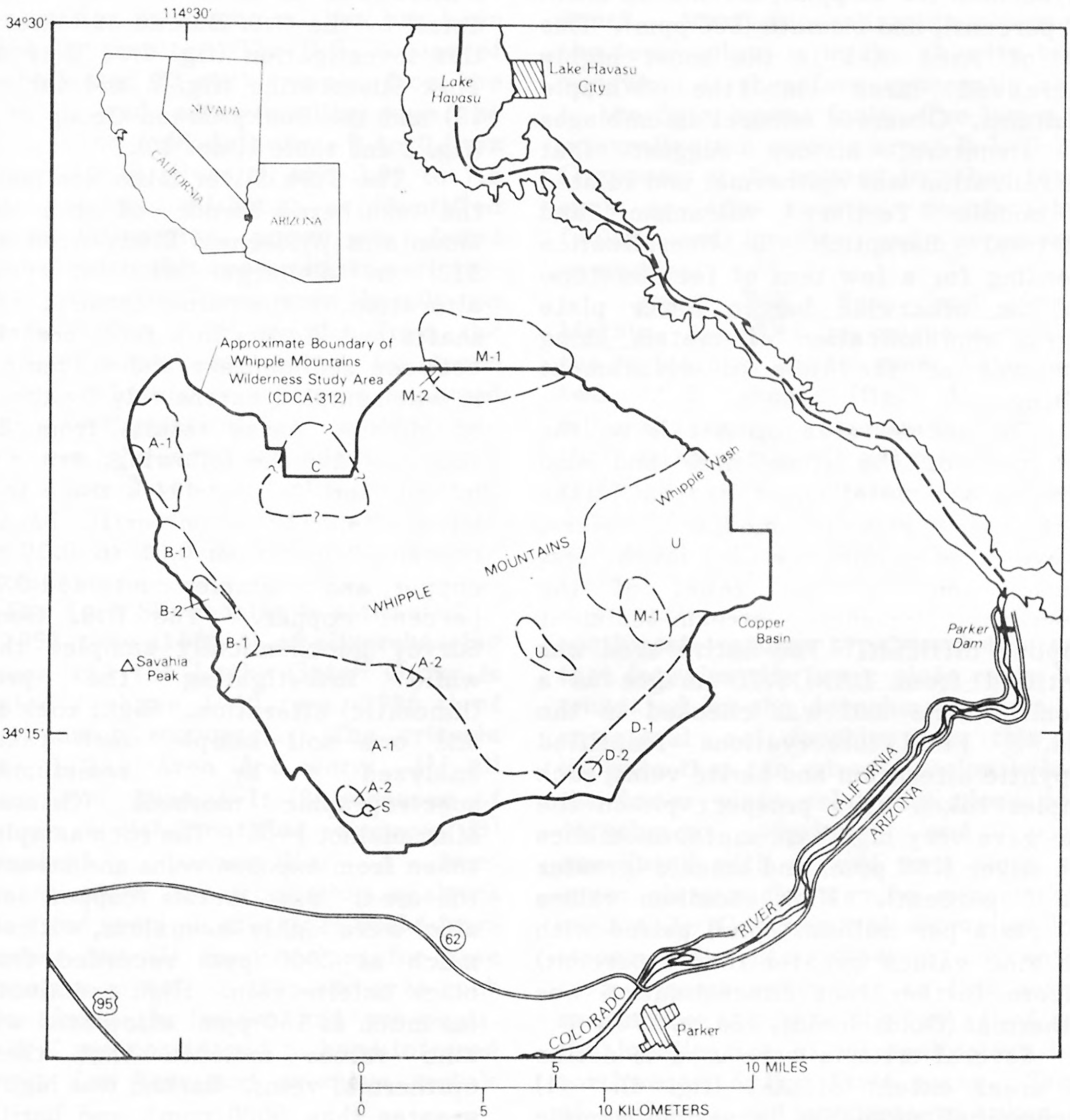


Figure 4.--Map showing the mineral resources of the Whipple Mountains Wilderness Study Area (CDCA-312), San Bernardino County, California. Letters denote areas of mineralization referred to in text. Boundary of Area C is queried as it is poorly defined.

molybdenum (15-20 ppm), arsenic (as much as 1 percent), and bismuth (300 ppm). This part of Area A-1 is the most highly mineralized area in the Whipple Mountains. Observed mineral assemblages and structural history suggest that mineralization was epithermal and related to middle Tertiary volcanism and structural disruption. Mineralization extending for a few tens of feet (meters) into the otherwise barren lower plate suggest remobilization of metals along structures at the time of detachment faulting.

The second area of A-1 is on the west side of the study area and also reflects base metal mineralization in the concentrate sample media. Here, however, mineralization is much less intense, and the low relief of the topography made stream-sediment sampling difficult. The entire area was identified from LANDSAT images as a limonitic zone and was checked in the field. Field observations identified propylitic alteration and barite veins; rock samples taken at a prospect pit in the zone gave very high base-metal anomalies with silver (150 ppm) and arsenic (greater than 1 percent). High cadmium values (300 parts per million (ppm)) paired with high zinc values (greater than 1 percent) indicate further that mineralization was epithermal (Goldschmidt, 154, p. 270).

Several criteria were used to define the areal extent of A-1 (fig. 4): (1) geochemical anomalies in various sample media for base metals (copper, lead, and zinc) with silver, arsenic, and molybdenum; (2) presence of several old mines and prospects; (3) favorable geologic terrane of highly faulted upper plate host rocks; and (4) areas of propylitic alteration and barite veining. Areas A-1 are considered to have hypothetical resources for base and precious metals (fig. 3).

Area A-2, Turk Silver mine and Lucky Green Group.--Within the southern part of area A-1 are two highly mineralized areas that were studied in detail by the U.S. Bureau of Mines during this investigation (fig. 4). They are the Turk Silver mine (fig. 2 and table 1, no. 13) and the Lucky Green Group of claims (fig. 2 and table 1, no. 20).

The Turk Silver mine lies just inside the southern border of the Whipple Mountains Wilderness Study Area (CDCA-312) in a large area of propylitic alteration. The mine consists of three shafts and 2 adits in a fault breccia zone between sedimentary and volcanic rocks; it was sampled extensively by the Bureau of Mines. Assay results from 27 rock samples gave the following: trace to 0.02 oz gold/ton (0.7 g gold/t), trace to 8.6 oz silver/ ton (293 g silver/t), 22 samples contained less than 0.01 to 0.09 percent copper, and 5 samples contained 0.2 to 3.5 percent copper. The U.S. Geological Survey geochemically sampled the area while investigating the propylitic (limonitic) alteration. Eight rock samples and one soil sample were taken and analyzed by semiquantitative spectrographic methods (Grimes and Marranzino, 1968). The rock samples were taken from exposed veins and structures in the area. Base metals (copper, lead, and zinc) were highly anomalous, with silver as much as 2000 ppm recorded from one black calcite vein. High cadmium values (as much as 150 ppm) associated with high zinc values indicate that these are epithermal veins. Barium was high (500 to greater than 5000 ppm), and barite veins were common. The soil sample taken near the mine also contained base metals and silver. W. J. Carr (written commun., 1982) suggested the Turk mine is on the same fault zone that in areas B-1 and B-2 is associated with mineralized lower plate rocks.

The Lucky Green Group lies in the northern part of area A-1 and is below but very near the Whipple Mountain detachment fault, in the chlorite breccia zone. Mining in the area consists of four large open cuts, several smaller cuts, two short adits, and numerous drill holes. The mineralization is in gneiss that has been intruded by granite. The U.S. Bureau of Mines collected 23 rock samples from the mine area, and assay results gave the following: no gold detected, 0 to 0.8 oz silver/ton (27 g silver/t), and 0.01 to 7.5 percent copper. Although no identified pervasive alteration zone was found associated with this area, quartz-sericite-chlorite alteration was seen locally on fractures. Two rock samples from the mineralized area were taken for trace element geochemistry and were analyzed by the semiquantitative spectrograph. Copper was the most abundant element (greater than 2 percent), but the rest of the suite of elements associated with mineralization in areas A-1 and A-2 were also present.

The Turk Silver mine is estimated to have 1957 tons (1528 t) of silver-bearing resources and the Lucky Green Group is estimated to have 1940 tons (1526 t) of copper-bearing resources. The criteria used to define Area A-2 were: (1) all criteria from Area A-1; (2) presence of known mines with identified resources; (3) geochemical anomalies from semiquantitative spectrographic analyses for base and precious metals in rocks from the areas; and (4) assay values for base and precious metals in chip and grab rock samples from the mines and prospects. Areas A-2 are considered to have inferred resources for base and precious metals (fig. 3).

Mineralization in lower plate of Whipple Mountains detachment fault.--The lower plate of the Whipple Mountains detachment fault is also lithologically varied and contains Proterozoic to Mesozoic or lower Cenozoic igneous and metamorphic rocks and their deeper, mylonitic equivalents according to Davis and others (1980, 1982a, 1982b). For the most part, the lower plate of the Whipple Mountains detachment fault is barren of mineralization and where mineralization is found, it rarely extends to any great depth. Most mineralization observed in the lower plate is in the chlorite breccia zone and is therefore apparently related to the detachment fault. The lower plate mineralization seen in areas B-1, B-2, and C appears to be related to other features such as dike swarms, postdetachment faults, and gravity and aeromagnetic anomalies.

Area B-1, Base and Precious Metals.--Area B-1 lies on the west edge of the wilderness study area, between the two A-1 areas (fig. 4). Here, mineralization is associated with faults that strike northwest and may be part of a regional northwest-trending structure defined by a gravity gradient to the north and south of the study area (Healy and Currey, 1980). Mineralization is 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 relationships in this area indicate that the mineralization is high in the lower plate relatively close to the detachment surface and possibly associated with a fault zone along which upper plate rocks may be mineralized in area A-2. Geochemical anomalies in the stream sediments and panned concentrates from stream sediments in this area are sparse, due partly to the low relief and to the localization of mineralization in the northwest-trending fault zones. Samples of sediment and concentrate taken from drainages cutting the mineralized fault zones contained highly anomalous values for copper and barium (in the 90th percentile or above) and varying amounts of lead (100-300 ppm), silver (3 ppm), molybdenum (10-15 ppm), and tungsten (200-500 ppm). This base-metal suite is slightly different than that seen in the upper plate as it is more closely related to primary sulfides than to the secondary carbonates and oxides. No pervasive altered (limonitic) zones were identified in area B-1 and analytical results from the leach of the intermediate magnetic fraction of the panned concentrates reflect this lack of iron and manganese oxides. There were only scattered low anomalies for molybdenum and one high copper anomaly, from a stream draining one of the mining areas.

The evidence used to define area B-1 (fig. 4) includes inferred extension of mineralized fault zones in the area, the dike swarm, the known mining activity for gold, silver, and copper in the area, an aeromagnetic anomaly, and electrical data giving evidence of alteration along a north-northwest trending structure at or near the New American Eagle mine. In addition to the above evidence, the criteria used for establishing area B-1 were (1) the position in the lower plate structurally near the Whipple Mountains detachment fault, and (2) geochemical anomalies in stream sediments and panned concentrates from stream sediments. Area B-1 is considered to have hypothetical resources for gold, silver, and copper (fig. 3).

<u>Area B-2, New American Eagle mine</u>.--In the course of this investigation the New American Eagle mine (figs. 2 and 4, table 1, no. 4) was studied in detail by the U.S. Bureau of Mines. This mine lies on the northwest-trending fault zone described in the section on area B-1 (fig. 4) and is in gneiss which has been intruded by the pre-detachment hypabyssal dike swarm. This mine consists of 2 shafts and several pits and cuts. It produced more than 700 tons (640 t) of ore that averaged about 8 percent copper and contained some gold and silver. The reported reserves in 1948 were 90,000 tons of ore containing 3.8 percent copper (Eric, 1948). Six chip and rock samples were taken during this investigation and assayed. They contained from 0.9 to 2.9 percent copper, nil to 0.44 oz gold/ton (15 g gold/t), and nil to 1.4 oz silver/ton (53 g silver/t). Five rock samples were taken from an outcrop at the mine for trace element geochemistry and were analyzed by semiquantitative spectrographic methods (Grimes and Marranzino, 1968). In addition, one sample was analyzed for gold, tungsten, antimony, arsenic, and mercury by atomic absorption methods (Ward and others, 1959; Welsh and Chao, 1975; Meir, 1980; and Leinz and Grimes, 1978) to see if this area of mineralization was related to a "gold" suite of elements indicative of epithermal precious metal vein systems. Gold and arsenic were the only elements found to be anomalous in these samples (gold = 12 ppm and arsenic = 20 ppm), and the existence of an epithermal precious metal vein system is considered unlikely. Most of these samples were taken at or near the contact of diorite dikes that intrude the area of the mine. Spectrographic results showed anomalies in copper (as much as 2 percent) and silver (as much as 300 ppm) with minor amounts of bismuth, molybdenum, lead, and zinc. The geochemistry of rocks taken from the mine area is characterized by a base and precious metal suite that is related to sulfide mineralization and higher temperatures than the carbonate-oxide deposits of the upper plate rocks.

As described earlier, the potential of this area was further investigated by an induced-polarization (IP) survey taken in the area of the New American Eagle mine. Results of this survey suggest the possibility of alteration and (or) sulfide mineralization extending to a depth of several hundred feet (meters) from the mine southeast along a northwest-trending structure for at least a mile (1.6 km).

Also included in area B-2 (fig. 4) are several other mines and prospects that occur in the same northwest-trending fault zone that have similar geologic settings, assay values, and geochemical expression. These are the D and W mine, the Sleepy Burro group, the Atkinson group, and four prospects (fig. 2, table 1, nos. 9, 3, 10, 5, 6, 7, and 8).

The criteria used to delineate area B-2 were the same as those used in area B-1 plus (1) the presence of sulfide mineralization at the New American Eagle mine, (2) identified reserves of copper ore, and (3) an induced polarization (IP) survey that suggests an extension of favorable terrane to the southeast. Area B-2 is considered to have inferred resources for copper, gold, and silver (fig. 3).

Area C, War Eagle mine.--This relatively large, poorly defined area lies astride the north boundary of the wilderness area and includes the War Eagle mine (figs. 2 and 4 and table 1, no. 2). The area is in the lower plate of the Whipple Mountains detachment fault, and may be in a thin plate above an even lower detachment fault of smaller offset (E. Frost, oral commun. 1982). Faults striking west-northwest have been mapped in this area by W. J. Carr (written commun., 1982). The rock assemblages in Area C are similar to those of Areas B-1 and B-2; for example, 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 in this investigation.

The U.S. Bureau of Mines studied the War Eagle mine in detail and collected 25 rock and chip samples from the area. Only one of the samples contained detectable gold; three contained minor silver. Thirteen samples contained from 0.01 to 0.17 percent copper. The mine area consists of 7 shafts, 5 trenches, and 11 pits and had an undetermined record of production of minor amounts of silver and copper ore with sulfides being reported at depth (Elliott, 1943). Geochemical anomalies from stream sediments and panned concentrates from stream sediments were sparse as the relief in Area C-1 is low and exposed mineralization is weak. A sample taken from a drainage in the vicinity of the War Eagle mine did contain anomalous copper, zinc, arsenic, and molybdenum in the leachate of the intermediate magnetic fraction of panned concentrate from stream sediment and also was anomalous in barite and copper in the nonmagnetic fraction of the concentrate. To better evaluate this area, three rock samples were taken at the mine for trace element geochemistry. The base and precious metal suite prevalent in Areas B-1 and B-2 is present but very subdued with anomalous (30-50 ppm) molybdenum in two samples.

Area C is best defined by geophysical data. Aeromagnetic gradients in the area suggest a northwest-trending structure through the mine area and an east-northeast-trending structure south of the mine. An induced-polarization (IP) survey in the mine area indicates alteration to a depth of at least 1000 ft (300 m) and suggests that the alteration may increase with depth.

Criteria used in delineating Area C (fig. 4) were: (1) geologic terrane similar to Area B-1, (2) aeromagnetic, gravity, and induced-polarization anomalies suggesting fault zones, mafic rocks, and alteration at depth, and (3) existence of mining activity with some record of production. Area C-1 is considered to have a speculative resource for base and precious metals (fig. 3).

Base and Precious Metal Mineralization Related To Granitic Plutons

Small outcrop areas of a Cretaceous granitic pluton occur along the southeast side of the Whipple Mountains Wilderness Study Area (CDCA-312). Copper mineralization occurs in or near several of these pluton outcrops, and it is inferred that at the time of detachment faulting a mineral deposit related to the Cretaceous quartz monzonite pluton overrode lower plate rocks. This dislocation broke up both the mineralized areas and the granite pluton along listric normal faults. The mineralization could also be associated with the detachment fault tectonic episode, as the geochemical suites observed are very similar to those in areas

A-1 and A-2. In addition, preexisting mineralization could have been remobilized at the time of detachment faulting.

Area D-1, potential mineralization.--Area D-1 traces the track of the possible dislocation of the granites from the vicinity of the Blue Cloud mine on the southwest to Copper Basin on the northeast (fig. 4). At Copper Basin, just east of the wilderness boundary, a mineral deposit has been extensively explored, where it 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 (Wilkens and Heidrich, 1982; E. Frost, written commun., 1982). Mineralization occurs in altered crystalline rocks of the upper plate adjacent to outcrop areas of the granite pluton and extends 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 crops out in two areas along the southeastern boundary of the wilderness study area in Area D-1. The southernmost area is near the Blue Cloud mine (fig.2 and table 1, no. 27) and the other area is approximately 1 mi (1.5 km) east-northeast of the Blue Cloud area. Semiquantitative spectrographic analyses of stream sediments, panned concentrates from stream sediments, and ICP analyses of the leachate from the intermediate magnetic fraction of the panned concentrates gave base metal anomalies with molybdenum being dominant. Small localized areas of remobilized mineralization are possible in both upper and lower plate rocks adjacent to the dislocated granite pluton. Three areas of alteration (limonitic) of undetermined type occur in Area D-1, possibly related to exposures of the chlorite breccia zone.

The criteria for establishing the areal extent of Area D-1 are: (1) the granite pluton, (2) geochemical anomalies in base metals and molybdenum, and (3) presence of alteration. Area D-1 has a speculative resource for base and precious metals (fig. 3).

Area D-2, Blue Cloud mine.--Area D-2 lies in the southwest part of Area D-1 and contains the Blue Cloud mine, which consists of 2 shafts, 5 adits, 2 trenches, and 10 prospect pits (figs. 2 and 4, Table 1, no. 27). The U.S. Bureau of Mines conducted a detailed investigation of the Blue Cloud mine during this study and collected 50 rock and chip samples. Gold was detected in three of the samples, and silver was detected in nine. Copper values ranged from 0.09 to 3.25 percent. The mine occurs in a hydrothermally mineralized and altered shear zone in mylonitic gneiss, near the detachment surface and high in the lower plate. The total identified resources are 235,000 tons (212,000 t) of ore containing 0.48 percent copper.

The criteria for establishing Area D-2 were, in addition to those for Area D-1, (1) presence of known mines and (2) identified resources of copper. Area D-2 has an indicated resource for copper (fig. 4).

Manganese Mineralization

Manganiferous deposits in the Whipple Mountains Wilderness Study Area (CDCA-312) are limited to upper plate Tertiary rocks and generally occur as lenticular, podiform, and irregular masses in limestone, sandstone, volcanic breccia, and as fissure filling in fanglomerate. Manganese mineralization occurs in association with the other hydrothermal alteration features and may be the result of volcanic activity that produced the Tertiary volcanic rocks exposed in the area.

Area M-1, potential mineralization.--There are two areas designated as M-1. One is centered around manganese occurrences just inside the eastern border of the wilderness study area, and the other, which contains the Stewart mine, is a large area of hydrothermal alteration along the northern border of the area (fig. 4).

The deposits just inside the eastern border of the study area (fig. 2 and table 1, nos. 35 through 38) are in the upper plate in northwest-striking bedding and structures (bedding-plane faults) in Tertiary volcanic and sedimentary rocks which dip moderately to steeply southwest. The lenticular to podiform bodies are generally less than 8 ft (2.4 m) wide and 25 ft (7.6 m) long. The deposits are generally conformable 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. The most productive deposit in this area was the Van Horn mine (fig. 2 and table 1, no. 35), which was investigated in detail by the U.S. Bureau of Mines during this study. The mine consists of one adit with three stopes to the surface. More than 700 tons (640 t) of ore with a manganese content of from 25 to 45 percent were produced. During this study 19 rock and chip samples were collected and analyzed for manganese, which ranged from 0.06 to 33.7 percent. The remainder of the manganese area on the eastern edge of the study area contains 8 adits, 6 trenches and 18 prospect pits (fig. 2 and table 1, nos. 36-38) having a combined production of more than 1700 tons (1540 t) of manganese ore (Trengove, 1960). Twenty-five rock and chip samples were taken from the area with from 0.03 to 22.8 percent manganese. Semiquantitative-spectrographic analyses of stream sediments from streams draining this area contained as much as 0.2 percent manganese. Analysis (ICP) of the leachate from the intermediate-magnetic fraction of panned concentrates from stream sediments taken in the area resulted in a range of from 0.15 to 0.9 percent manganese.

The second manganese area is located along the northern border of the wilderness study area (fig. 4) 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 from stream sediments. Zinc, arsenic, lead, copper, and barium were also anomalous in these samples, suggesting an epithermal mineralizing event. During this study geochemists from the U.S. Geological Survey visited this altered (limonitic) area and sampled rocks from several manganese prospects for trace-element geochemistry. Two types of rock were sampled; siliceous manganese ore and red and brown iron-oxide-stained jasperoid from a fanglomerate. The manganese sample contained silver (50 ppm), arsenic (300 ppm), barium (greater than 0.5 percent), beryllium (10 ppm), copper (3000 ppm), molybdenum (100 ppm), lead (2000 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 contained a similar but subdued suite minus the silver, beryllium, and tungsten.

The criteria used in delineating Area M-1 were, (1) mines and prospects for manganese, (2) solfataric alteration, and (3) proximity to Tertiary volcanic rocks. These areas are a hypothetical resource for manganese (fig. 3).

Area M-2, Stewart mine.—The Stewart mine (fig. 2 and table 1, no. 1) is located at the north edge of the wilderness area, adjacent to the west edge of the large altered (limonitic) area, M-1 (fig. 4). The mine consists of three adits and numerous prospect pits and was investigated in detail by the U.S. Bureau of Mines during this study. The manganese occurs as fissure-fillings and consists of pyrolusite with subordinate psilomelane. Hematite, limonite, and calcite are common gangue minerals. The thickest part of this deposit measures 3.5 ft (1.1 m). Fractures which localized these minerals strike from N. 15° W. to N. 40° W. and dip southwest; they can be traced only a few tens of feet. Alteration associated with the manganiferous deposits appears to be of dominantly siliceous character. More than 100 tons (91 t) of ore containing from 35.84 to 39.66 percent manganese were produced. Eleven rock and chip samples were taken during this study, and they ranged from 6.0 to 64 percent manganese. The Stewart mine area contains approximately 2,575 tons (2,150 t) of inferred manganiferous resources.

The criteria used in establishing Area M-2 were, (1) criteria for Area M-1 and (2) inferred manganese resources. Area M-2 is considered to be an inferred resource for manganese (fig. 3).

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.

Area S, decorative building stone.—Thin to very thinly bedded limestone, cherty limestone, and sandy limestone crop out in many places in the study area; it has been quarried in the southwestern portion of the study area (fig. 4). The deposit covers an estimated 640 acres (259 ha) (fig. 2 and table 1, no. 15). The flagstone-like material is commonly tan to gray with occasional reddish-stained laminae and partings. Individual fragments range from a few square inches to rarely larger than 2 sq ft (0.2 m^2), and in thickness from less than 1/2 in. (1.3 cm) to 4 in. (10 cm). 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 which is obtained from unweathered material beneath the surface. Obviously, 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 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.

The criteria used to establish Area S were, (1) suitable rock type of thin-bedded, cherty limestone and sandy limestone, and (2) an identified resource of 1008 tons (910 t) of building stone. Area S is considered to have a measured resource for building stone (fig. 3).

Geothermal Resources

No known geothermal potential exists within the Whipple Mountains Wilderness Study Area (CDCA-312).

Uranium

Two areas of potential uranium mineralization (area U, fig. 4) occur in the eastern part of the study area. Both areas contain Tertiary sedimentary rocks (including lacustrine sedimentary rocks) and volcanic rocks of the upper plate of the Whipple Mountains detachment fault.

Alteration (limonitic) appears to be solfataric and could have provided a mechanism for redistribution and localization of any uranium concentrations. Ground scintillometer readings taken at sample sites during this study were anomalous in Area U and anomalous uranium was detected in the National Uranium Resource Evaluation (NURE) aeroradiometric data (J. Otton, written commun.,1982). These NURE anomalies generally have moderate potassium and high uranium which in this region commonly characterize uranium-enriched sedimentary rocks.

Criteria for defining Areas U were, (1) favorable NURE data, (2) favorable geologic terrane, (3) ground scintillometer readings, and (4) solfataric alteration. Areas U are considered to have a speculative resource potential for uranium (fig. 3).

Oil and Gas

The Whipple Mountains Wilderness Study Area (CDCA-312) is considered unfavorable for oil and gas. 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. 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 potential for oil and gas does not warrant classification as a resource.

SUMMARY ASSESSMENT OF MINERAL-RESOURCE POTENTIAL

The mineral resource potential of the Whipple Mountains Wilderness Study Area (CDCA-312) was classified using the McKelvey diagram, according to definitions established by the U.S. Bureau of Mines and the U.S. Geological Survey (1980). Seven categories of mineral resource potential are classified in figure 4 and are: base and precious metal mineralization in the upper plate of the Whipple Mountains detachment fault, Area A-1 (hypothetical resource potential) and specific mines (Area A-2) with inferred mineral-resource potential; base and precious metal mineralization in the lower plate of the Whipple Mountains detachment fault, Area B-1 (hypothetical mineral-resource potential), specific mines (Area B-2) with inferred mineral-resource potential, and Area C (speculative mineral-resource potential); base and precious metal mineralization related to granitic plutons, Area D-1 (speculative mineral-resource potential) and a specific mine with indicated mineral-resource potential in Area D-2; manganese mineralization related to Tertiary volcanic rocks in Area M-1 (hypothetical mineral-resource potential) and specifically inferred mineral-resource potential at M-2; identified mineral resource of decorative stone at Area S; and speculative mineral resource potential for uranium mineralization in Tertiary lake bed sediments in areas U. The potential for geothermal, placer gold, and oil and gas were also evaluated and no resources were identified.

The mineral-resource potential of the Whipple Mountains Wilderness Study Area (CDCA-312), as assessed in the joint study by a team of U.S. Geological Survey and U.S. Bureau of Mines scientists, relies heavily on geologic environment, geochemical surveys, mine and prospect evaluations, and hydrothermal alteration studies. Most of the known mineralization in the Whipple Mountains Wilderness Study Area (CDCA-312) 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 lower plate rocks on the west side of the area (Areas B-1 and B-2, fig. 4). Here mineralization appears more related to a hypabyssal dike swarm, localized along late normal faults that cut both upper and lower plate rocks. Area C in lower plate rocks (fig. 4) also includes dike rocks and faulting.

Geochemically the mineralization in the Whipple Mountains Wilderness Study Area (CDCA-312) is predominantly a base metal suite of copper, lead, and zinc with copper predominating. Precious metals (gold and silver) are associated with the base metal suite, with concentrations varying from area to area. Barium is ubiquitous throughout the area in both upper and lower plate rocks, but rarely far (vertically) from the detachment fault surface, attesting to redistribution of mineralization by meteoritic waters along the detachment fault. Manganese appears universally associated with Tertiary volcanic rocks in the upper plate and solfataric alteration.

The conceptual model for mineralization in the Whipple Mountains Wilderness Study Area (CDCA-312) 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 mineralization probably occurred prior to detachment faulting, with conduction of fluids and redistribution of mineralization provided by listric normal and antithetic fault conduits formed during dislocation of the upper plate. Syntectonic volcanism could also have provided a source of metallic elements and manganese.

REFERENCES CITED

Anderson, J. L., and Frost, E. G., 1981, Petrologic, geochronologic, and structural evaluation of the allochthonous crystalline terrane in the Copper Basin area, Eastern Whipple Mountains, southeastern California: February 1981, unpublished report, 63 p.

Anderson, J. L., 1981, Conditions of mylonitization in a Cordilleran metamorphic complex, Whipple Mountains, California, in Tectonic framework of the Mojave and Sonoran Deserts, California and Arizona: U.S. Geological Survey Open-File Report 81-503, p. 1-3.

Anderson, J. L., and Rowley, M. C., 1981, Synkinematic intrusion of two-mica and associated metaluminous granitoids, Whipple Mountains, California: Canadian Mineralogist, v. 19, p. 83-101.

Anderson, J. L., Davis, G. A., and Frost, E. G., 1979, Field guide to regional Miocene detachment faulting and early Tertiary(?) mylonitization, Whipple-Buckskin-Rawhide Mountains, southeastern California and western Arizona; in Geologic Excursions in the southern California area, Abbott, P. L., ed., San Diego State University, San Diego, California.

Aubury, L. E., 1908, The copper resources of California: California Mining Bureau Bulletin 50, 366 p.

Bailey, G. E., 1902, The saline deposits of California: California State Mining Bureau Bulletin 24, 216 p.

Bancroft, Howland, 1911, Ore deposits in northern Yuma County, Arizona: U.S. Geological Survey Bulletin, 451, 130 p.

Blanchard, Roland, 1968, Interpretation of leached outcrops: Nevada Bureau of Mines, Bulletin 66, p. 7.

Cameron, T.E. and Frost, E. G., 1981, Regional development of major anitforms and synforms coincident with detachment faulting in California, Arizona, Nevada, and Sonora: Geological Society of America Abstracts with Programs, v. 13, no. 7, p. 421-422.

Carr, W. J. and Dickey, D. D., 1980, Geologic map of the Vidal, California and Parker SW, California-Arizona quadrangles: U.S. Geological Survey Miscellaneous Investigations Map I-1125.

Carr, W. J., 1981, Tectonic history of the Vidal-Parker region, California and

Arizona, in Tectonic framework of the Mojave and Sonoran Deserts, California and Arizona: U.S. Geological Survey Open-File Report 81-503, p. 18-20.

Carr, W. J., Dickey, D. D., and Quinlivan, W. D., 1980, Geologic map of the Vidal NW, Vidal Junction, and parts of the Savahia Peak SW and Savahia Peak quadrangles, San Bernardino County, California: U.S. Geological Survey Miscellaneous Investigations Map I-1126.

Chapman, R. H., and Rietman, J. D., 1978, Bouguer gravity map of California, Needles Sheet: California Division of Mines and Geology, scale 1:250,000.

Church, S. E., 1981, Multi-element analyses of fifty-four geochemical reference samples using inductively coupled plasma-atomic emission spectrometry: Geostandards Newsletter, v. V, no. 2, October 1981, p. 133-160.

Church, S. E., Motooka, J. M., Bigelow, R. C., Van Trump, George, Jr., 1982, Application of an ICP-AES system to exploration research, in Barnes, R. M., 1982 Winter Conferense on Plasma Spectro-Chemistry, Orlando, Florida; Amherst, University of Massachusetts Press, p. 45-46.

Cloudman, H. C., Huguenin, E., and Merrill, F.J.H., 1919, San Bernardino County, in Mines and mineral resources of California: Report XV of the State Mineralogist, Part VI, California State Mining Bureau, p. 775-889.

Coney, P. J., 1980, Cordilleran metamorphic core complexes: An overview: Geological Society of America Memoir 153, p. 7-31.

Crittenden, M. D., Coney, P. J., and Davis, G. H., 1980, eds., Cordilleran metamorphic core complexes: Geological Society of America Memoir 153, 490 p.

Davis, G. A., Anderson, J. L. Frost, E. G. and Shackelford, T. J., 1980, Mylonitization and detachment faulting in the Whipple-Buckskin-Rawhide Mountains terrance, southeastern California and western Arizona: in Crittenden, M. D., Davis, G. A., and Coney, P. J., eds., 1980, Cordilleran metamorhpic core complexes, Geological Society of America Memoir 153, p. 79-129.

Davis, G. A., Anderson, J. L., Martin, D. L., Krummenacher, D., Frost, E. G. and Armstrong, R. L., 1982a, Geologic and geochronologic relations in the lower plate of the Whipple detachment fault, Whipple Mountains, southeastern California: A progress report, in Frost, E. G. and Martin, D. L., eds., 1982, Mesozoic-Cenozoic Tectonic Evolution of the Colorado River Region, California, Arizona, and Nevada (Anderson-Hamilton Volume): San Diego, Cordilleran Publishers, p. 408-432.

Davis, G. A., Anderson, J. L, and Frost, E. G., 1982b, Geologic map of the Whipple Mountains Wilderness Study Area: U.S. Geological Survey Miscellaneous Field Studies Map MF-(in press)

Dickey, D. D., Carr, W. J., and Bull, W. B., 1980, Geologic map of the Parker NW, Parker and parts of the Whipple Mountains SW and Whipple Wash quadrangles, California and Arizona, U.S. Geological Survey Miscellaneous Investigations Map I-1124.

Elliott, R., 1943, Virginia Copper Group (War Eagle Claims), San Bernardino County, California: U.S. Bureau of Mines property file report, 6 p.

Eric, J. H., 1948, Tabulation of copper deposits in California, in Copper in California: California Division of Mines Bulletin 144, Part 3, p. 199-429.

Evans, K. V., 1979, Structural geology of the eastern Whipple Mountains, San Bernardino County, California: unpublished M.S. Thesis, University of Southern California, 128 p.

Fleury, Bruce, 1961, The geology, origin, and economics of manganese at Roads End, California: unpublished M.A. Thesis, University of Southern California, 96 p.

Frost, E. G., 1979, Growth-fault character of Tertiary detachment faulting, Whipple Mountains, southeastern California, and Buckskin Mountains, western Arizona: Geological Society of America Abstracts with Programs, v. 11, no. 7, p. 429.

Frost, E. G., 1980, Appraisal design data, structural geology and water-holding capability of rocks in the Whipple Wash area, San Bernardino County, California: unpublished report for United States Water and Power Resources Service Lower Colorado Regional Office, Boulder City, Nevada, June 1980, P.O. 0-01-30-07110, 88 p.

Frost, E. G., and Martin, D. L., eds., 1982, Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona and Nevada (Anderson-Hamilton volume): San Diego, Cordilleran Publishers, 608 p.

Goldschmidt, V. M., 1954, Geochemistry: Oxford, Clarendon Press, 730 p.

Graeff, F. W., 1910, Nitrate deposits of southern California: Engineering and Mining Journal, v. 90, p. 173.

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

Hamilton, Warren, 1982, Structural evolution of the Big Maria Mountains, northeastern Riverside County, southeastern California, in Frost, E. G., and Martin, D. L., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada: San Diego, Cordilleran Publishers, p. 1-28.

Healey, D. L., and Currey, F. E., 1980, Complete Bouguer gravity anomaly map of the Vidal area, California and Arizona: U.S. Geological Survey Open-File Report 80-619, 16 p.

Howard, K. A., Goodge, J. W., and John, B.E., 1982, Detached crystalline rocks of the Mohave, Buck, and Bill Williams Mountains, western Arizona, in Frost, E. G. and Martin, D. L., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada: San Diego, Cordilleran Publishers, p. 377-392.

Hunt, G. R., 1980, Electromagnetic radiation: the communication link in remote sensing, in Siegal, B. S., and Gillespie, A. R., Remote sensing in geology: New York, John Wiley and Sons, p. 5-45.

Jones, E. L., Jr., 1920, Depostis of manganese ore in southeastern California: U.S. Geological Survey Bulletin 710-E, p. 185-208.

Leinz, R. W., and Grimes, D. J., 1978, Spectrochemical determination of submicrogram amounts of tungsten in geologic materials: U.S. Geological Survey Journal of Research, v. 6, no. 2, p. 259-262.

Light, T. D., Marsh, S. P., and Raines, G. L., 1982, Mineralization in the Crossman Peak area, Mohave Mountains, Arizona: Geological Society of America Abstracts with Programs, (in press).

Marsh, S. P., Detra, D. E., and McDougal, C. M., 1982, Spectrographic analyses and statistical data for stream sediment, panned concentrate from stream sediment, and rock samples from the Whipple Mountains Wilderness Study Area, San Bernardino County, California: U.S. Geological Survey Open-File Report (in press)

Marsh, S. P., and Erickson, R. L., 1974, Integrated geologic and geochemical studies, Edna Mountains, Nevada, in

Elliot, I. L., and Fletcher, W. K., eds.: Geochemical Exploration 1974, Elsevier Scientific Publishing Company, p. 239-250.

Meier, A. L., 1980, Flameless atomic-absorption determination of gold in geologic materials: Journal of Geochemical Exploration, v. 13, no. 1, p. 77-85.

Miller, C. F., Howard, K. A., and Hoisch, T.D., 1982, Mesozic thrusting, metamorphism, and plutonism, Old Woman-Piute Range, southeastern California, in Frost, E. G. and Martin, D. L., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada: San Diego, Cordilleran Publishers, p. 561-581.

Raines, G. L., 1982, Preliminary map of limonitic hydrothermal alteration for portions of the Needles 1^{o} x 2^{o} quadrangle, Arizona and California: U.S. Geological Survey Open-File Report (in press).

Reynolds, S. J., Keith, S. B., and Coney, P. J., 1980, Stacken overthrusts of Precambrian crystalline basement and inverted Paleozoic sections emplaced over Mesozoic strata, west-central Arizona: Arizona Geol. Digest, v. 12, p. 45-52.

Ridenour, J., Moyle, P. R., and Willett, S. L., 1982, Mineral occurrences in the Whipple Mountains Wilderness Study Area, San Bernardino County, California, in Frost, E. G., and Martin, D. L., eds., Mesozic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada: San Diego, Cordilleran Publishers, p. 69-76

Root, W. A., 1909, Mining in western Arizona and eastern California: The Mining World, v. 30, no. 20, p. 929-932.

Rowan, L. C., Wetlaufer, P. H., Goetz, A.F.H., Billingsley, F. C., and Stewart, J. H., 1974, Discrimination of rock types and detection of hydrothermally altered areas in south-central Nevada by the use of computer enhanced ERTS images: U.S. Geological Survey Professional Paper 883, 35 p.

Shumway, G. L., Vredenburgh, L., and Hartill, R. D., 1980, Desert fever: an overview of mining in the California Desert Conservation Area: prepared for the Desert Planning Staff, Bureau of Land Management, Riverside, California, Contract No. CA-060-CT7-2776, p. 49-53.

Stevens, H. J., 1911, The Copper Handbook, v. 10: H. J. Stevens, Houghton, Michigan, 1902 p.

Stone, Paul, and Howard, K. A., 1979, Compilation of geologic mapping in the Needles 1^{o} x 2^{o} sheet, California and Arizona: U.S. Geological Survey Open-File Report 79-388, scale 1:250,000.

Teel, D. B. and Frost, E. G., 1982, Synoragenic evolution of the Copper Basin Formation in the eastern Whipple Mountains, San Bernardino County, California , in Frost, E. G. and Martin, D. L., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada: San Diego, Cordilleran Publishers, p. 275-286.

Thurn, L., 1982, Interpretation of age relationships and deformational history, southeastern Whipple Mountains, California, in Frost, E.G., and Martin, D. L., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada: San Diego, Cordilleran Publishers, p. 511-517.

Trask, P. D., 1950, Geologic description of the manganese deposits of California: California Division of Mines Bulletin 152, 378 p.

Trask, P. D., Wilson, I. F., and Simons, F. S., 1943, Manganese deposits of California--a summary report, in Manganese in California: California Division of Mines Bulletin 125, p. 51-215.

Trengove, R. R., 1960, Reconnaissance of California manganese deposits: U.S. Bureau of Mines Report of Investigations 5579, 46 p.

Tucker, W. B., and Sampson, R. J., 1930, San Bernardino County, Los Angeles Field Division, in Mining in California: Report XXVI of the State Mineralogist, v. 26, no. 3, California Division of Mines, p. 202-325.

_______ 1931, San Bernardino County, Los Angeles Field Division, in Mining in California: Report XXVII of the State Mineralogist, v. 27, no. 3, California Division of Mines, p. 243-406.

_______ 1943, Mineral resources of San Bernardino County, in Quarterly chapter of State Mineralogist's Report XXXIX: California Journal of Mines and Geology, v. 39, no. 4, p. 421-609.

Turner, H. W., 1907, The sodium nitrate deposits of the Colorado: Mining and Science Press, v. 94, p. 634-635.

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, 5 p.

U.S. Department of the Interior, Bureau of Land Management, 1980, Final Environmental Impact Statement and proposed plan, California Desert Conservation Area, volume B., Appendix III: Wilderness, p. 557-562.

U.S. Geological Survey, 1981, Aeromagnetic map of the Needles 1° by 2° Quadrangle, California and Arizona: U.S. Geological Survey Open-File Report 81-85.

Ward, F. N., Nakagawa, H. M., Harms, T. F., and Van Sickle, G. H., 1959, Atomic absorption methods of analysis useful in geochemical exploration: U.S. Geological Survey Bulletin 1289, 45 p.

Welsch, E. P., 1979, Determination of As in geologic materials with silver diethyldithiocarbamate: U.S. Geological Survey Open-File Report 79-1442, 10 p.

Wilkins, J. and Heidrick, T. L., 1982, Base and precious metal mineralization related to low-angle tectonic features in the Whipple Mountains, California and Buckskin Mountains, Arizona, in Frost, E.G., and Martin, D. L., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada: San Diego, Cordilleran Publishers, p. 182-204.

Wright, L. A., Stewart, R. M., Gay, T. E., Jr., and Hazenbush, G. C., 1953, Mines and mineral deposits of San Bernardino County, California, in California Division of Mines, v. 49, nos. 1 and 2, p. 49-192.