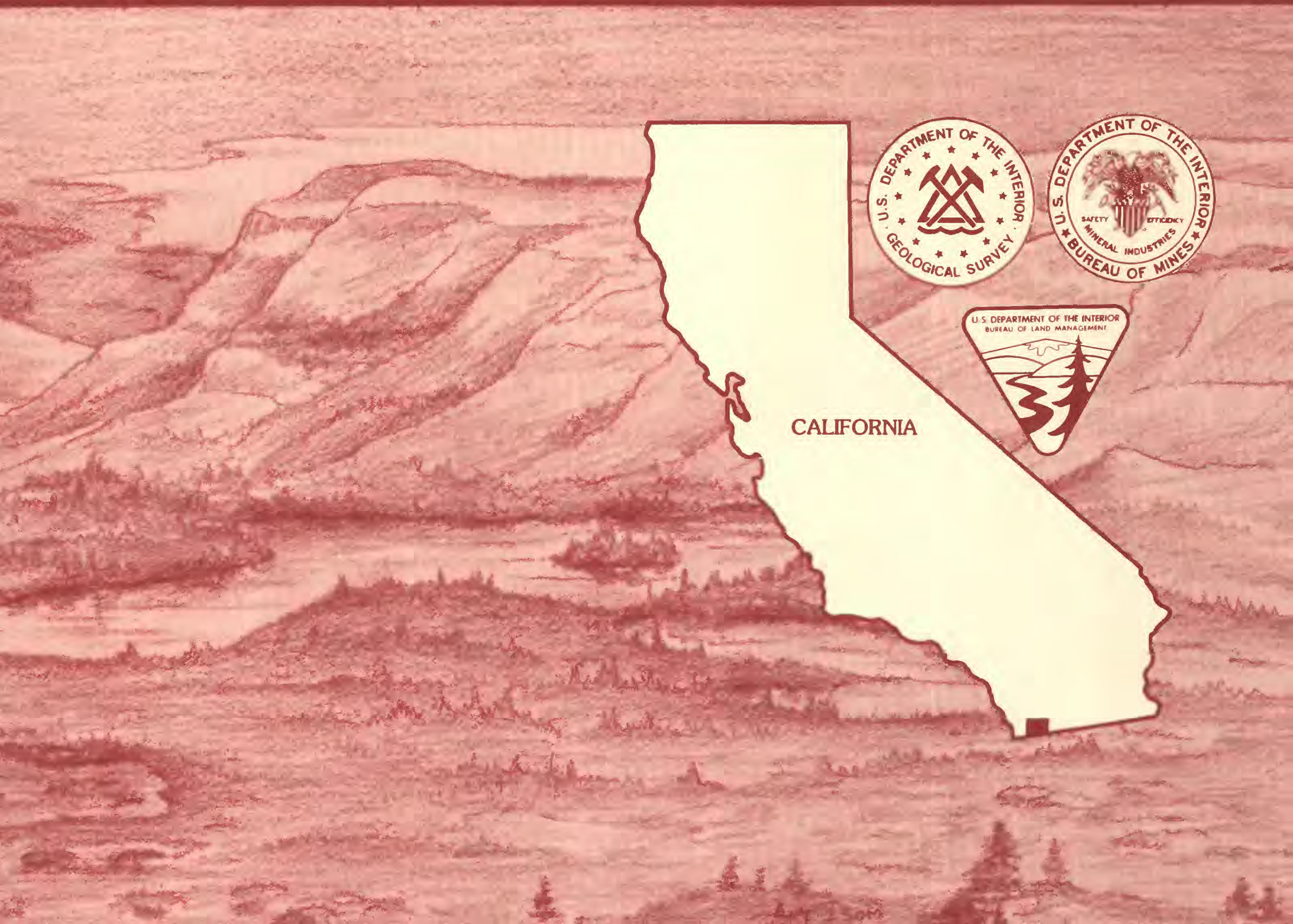
Mineral Resources of the Sawtooth Mountains and Carrizo Gorge/Eastern McCain Valley Wilderness Study Areas, San Diego County, California

U.S. GEOLOGICAL SURVEY BULLETIN 1711–B



STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of mineral surveys for part of the Sawtooth Mountains (CA-060-024B) Wilderness Study Area, San Diego County, California and for the Carrizo Gorge/Eastern McCain Valley (CA-060-025A) Wilderness Study Area, San Diego County, California.

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Mineral Resources of the Sawtooth Mountains and Carrizo Gorge/Eastern McCain Valley Wilderness Study Areas, San Diego County, California

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SUMMARY

Abstract

This report presents the results of mineral surveys of part of the Sawtooth Mountains (CA-060-024B) Wilderness Study Area and all of the Carrizo Gorge/Eastern McCain Valley (CA-060-025A) Wilderness Study Area. In this report, the areas studied are referred to as "the wilderness study areas", or simply "the study areas." The Sawtooth Mountains and Carrizo Gorge/Eastern McCain Valley study areas encompass approximately 24,696 and 14,573 acres, respectively, in eastern San Diego County, California. Field work for this report was carried out during 1983 and 1984. No mineral resources or resource potential have been identified in the Sawtooth Mountains Wilderness Study Area. The study area contains extensive sand and gravel occurrences, but these occurrences are not considered resources because similar ones are present closer to population centers such as San Diego and El Centro. The Carrizo Gorge/Eastern McCain Valley Wilderness Study Area has moderate potential for resources of undiscovered gem-grade minerals (kunzite, aquamarine) in pegmatite dikes in the vicinity of Mount Tule in the western part of the study area. No oil, gas, coal, or geothermal resources were identified in either of the study areas.

Character and Setting

The Sawtooth Mountains and Carrizo Gorge/Eastern McCain Valley Wilderness Study Areas have been combined into a single report because they are geographically close and have similar geologic settings. The Sawtooth Mountains and Carrizo Gorge/Eastern McCain Valley Wilderness Study Areas occupy approximately 24,696 and 14,573 acres, respectively, in eastern San Diego County, Calif. They are located about 40 and 50 mi east of San Diego, respectively (fig. 1). The study areas lie within a transitional physiographic zone between the Peninsular Range province, the mountainous spine of Alta and Baja California to the west, and the Colorado Desert to the east. This zone is characterized by rugged topography and has a semiarid to arid climate. Conifer forests occupy the higher mountain ridges, and chapparal-desert plant communities are found at lower elevations. Topographic relief in the study areas ranges from about 3,800 to 4,100 ft.

The Sawtooth Mountains and Carrizo Gorge/Eastern McCain Valley Wilderness Study Areas are underlain by Cretaceous (63 to 138 million years before present (Ma); see appendix for geologic time scale) plutonic rocks of the Peninsular Ranges batholith that form much of the crystalline bedrock of the Peninsular Ranges. The batholith is composed of a variety of deformed Early Cretaceous plutons that were intruded by relatively undeformed younger Cretaceous plutons. These plutons intruded metamorphosed Paleozoic (240 to 570 Ma) and Mesozoic (63 to 240 Ma) sedimentary and volcanic rocks, remnants of which are exposed as steeply dipping tabular bodies, or screens, between the plutons. Patches of Cenozoic (63 Ma to present) alluvial deposits unconformably overlie the uplifted and deeply eroded batholith in both study areas. Faults of various ages cut the batholithic rocks. In the Sawtooth Mountains Wilderness Study Area, some faults cut Quaternary alluvium.

Small gold deposits are found in metasedimentary rocks in the Deer Park and Laguna Mountains mining districts, about 4 mi west of the Sawtooth Mountains Wilderness Study Area. There is no record of mining activity in similar metasedimentary rocks within the study area, and no gold or other mineral

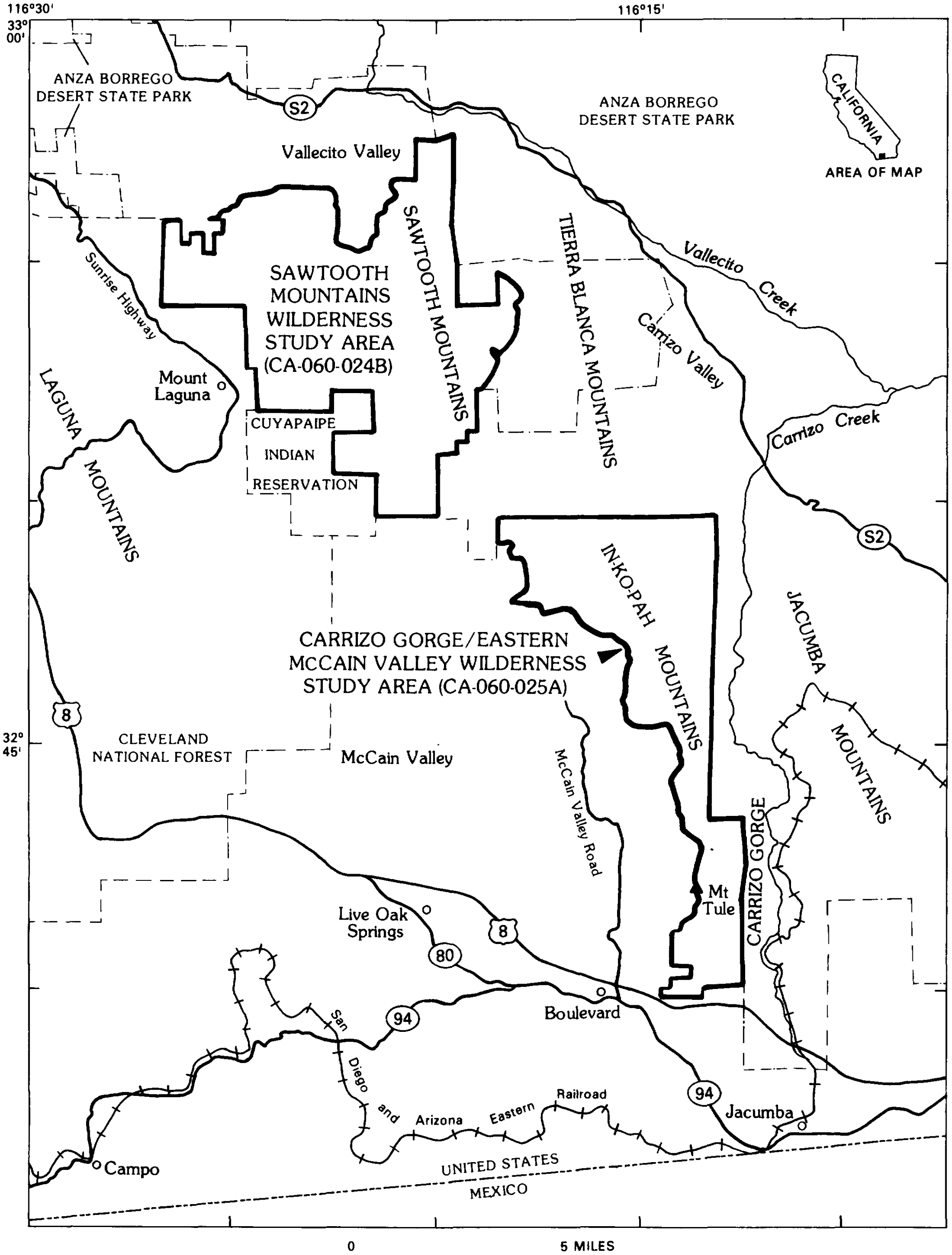


Figure 1. Index map showing location of Sawtooth Mountains and Carrizo Gorge/Eastern McCain Valley Wilderness Study Areas, San Diego County, California.

resources were found during this study. The Carrizo Gorge/Eastern McCain Valley Wilderness Study Area contains no mines, and no mineral resources were identified during this study. Two gem-producing mines are located in pegmatite dikes adjacent to the west boundary of the study area, and similar pegmatite dikes occur within the study area in the vicinity of Mount Tule.

Mineral Resources and Mineral Resource Potential of the Sawtooth Mountains Wilderness Study Area

No mineral resources or resource potential have been identified in the Sawtooth Mountains Wilderness Study Area although evidence of minor mineralization is present. Two prospects in the western part of the study area revealed pegmatite and quartz veins in pelitic schist (fig. 2), a geologic environment similar to that of gold-bearing mineralized zones about 4 mi west of the study area. Samples from the two prospects in the study area contained no significant metal concentrations. A reconnaissance geochemical survey of stream sediments revealed widespread tungsten and tin anomalies as well as localized silver, barium, copper, bismuth, and lead anomalies. These geochemical anomalies are probably related to the abundances of particular rock types within the study area and do not indicate resources. The above data, and the absence of mining activity in the area, indicate that there is no potential for undiscovered mineral resources. Sand and gravel occurrences exist but are not considered resources at this time because of the high cost of transporting these materials to population centers. No potential for undiscovered oil and gas or other energy resources was identified in the study area.

Mineral Resources and Mineral Resource Potential of the Carrizo Gorge/Eastern McCain Valley Wilderness Study Area

No mineral resources have been identified; however, available data suggest that the Carrizo Gorge/Eastern McCain Valley Wilderness Study Area has moderate potential for gem-grade minerals in pegmatite dikes near Mount Tule (fig. 3). Two active mines adjacent to the west boundary of the study area near Mount Tule have produced significant quantities of gem-grade aquamarine and kunzite from pegmatite dikes that cut a large screen consisting of gabbro, tonalite, and metasedimentary rocks. Many lithologically similar dikes are present within the study area in the Mount Tule area and detailed exploration of them might disclose gem-bearing pockets. Scattered exposures of manganiferous rocks in the study area are too small to be considered resources. A reconnaissance geochemical survey of stream sediments disclosed widespread tungsten and tin anomalies as well as locally high concentrations of boron, bismuth, molybdenum, and barium. In most cases, these anomalies are related to the abundances of specific rock types within the study area and do not indicate the existence of mineral resources. No mineral or sand and gravel resources were identified in the study area. No potential for undiscovered oil and gas or other energy resources was determined in the study area.

INTRODUCTION

Area Descriptions

This report presents the results of mineral surveys of part of the Sawtooth Mountains (CA-060-024B) Wilderness Study Area and all of the Carrizo Gorge/Eastern McCain Valley Wilderness Study Area. In this report, the areas studied are referred to as "the wilderness study areas", or simply "the study areas." The Sawtooth Mountains and Carrizo Gorge/Eastern McCain Valley Wilderness Study Areas are located about 40 and 50 mi east, respectively, of San Diego, Calif., where they comprise approximately 24,696 and 14,573 acres, respectively (fig. 1). In this region, a subdued upland surface that forms the crest of the Peninsular Ranges is succeeded to the east by rugged desert mountain ranges and alluviated valleys. The climate is semiarid to arid; vegetation varies from pinyon-juniper-mountain mahogany woodlands at higher elevations, through a mixed chaparral-sage-desert flora at intermediate elevations, to a true desert community that includes agave and cactus with isolated palm groves at the heads of canyons.

The Sawtooth Mountains Wilderness Study Area includes part of the deeply incised eastern escarpment of the Laguna Mountains; elevations range from about 5,900 ft at the edge of the escarpment to about 1,800 ft in the desert valley below. Sunrise Highway provides access to the western part of the study area and the northern part can be reached by unimproved dirt roads that lead up several large canyons. McCain Valley Road originates at California Highway 80 in Boulevard and provides access to the southern part of the area.

The Carrizo Gorge/Eastern McCain Valley Wilderness Study Area is located in the In-ko-pah Mountains and includes part of the McCain Valley National Cooperative Land and Wildlife Management Area on the west. The south boundary of the study area lies less than 1 mi north of Interstate 8. The study area encompasses part of the western wall of a spectacular gorge cut by northward-flowing Carrizo Creek. Elevations range from 4,647 ft on Mount Tule to about 800 ft in lower Carrizo Canyon; peaks named Grunt, Gasp, and Groan suggest the ruggedness of the terrain in and near the study area. The western part of the area can be reached from McCain Valley Road by an unimproved dirt road to Sacotone Spring (fig. 3). Access to the northern part of the area is from County Road S-2, while the eastern part is accessible from Dubber Spur, a siding on the presently defunct San Diego and Arizona Eastern Railroad.

Previous and Present Investigations

This mineral resource study is a joint effort by the U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (USBM). The history and philosophy of such joint mineral surveys of U.S. Bureau of Land

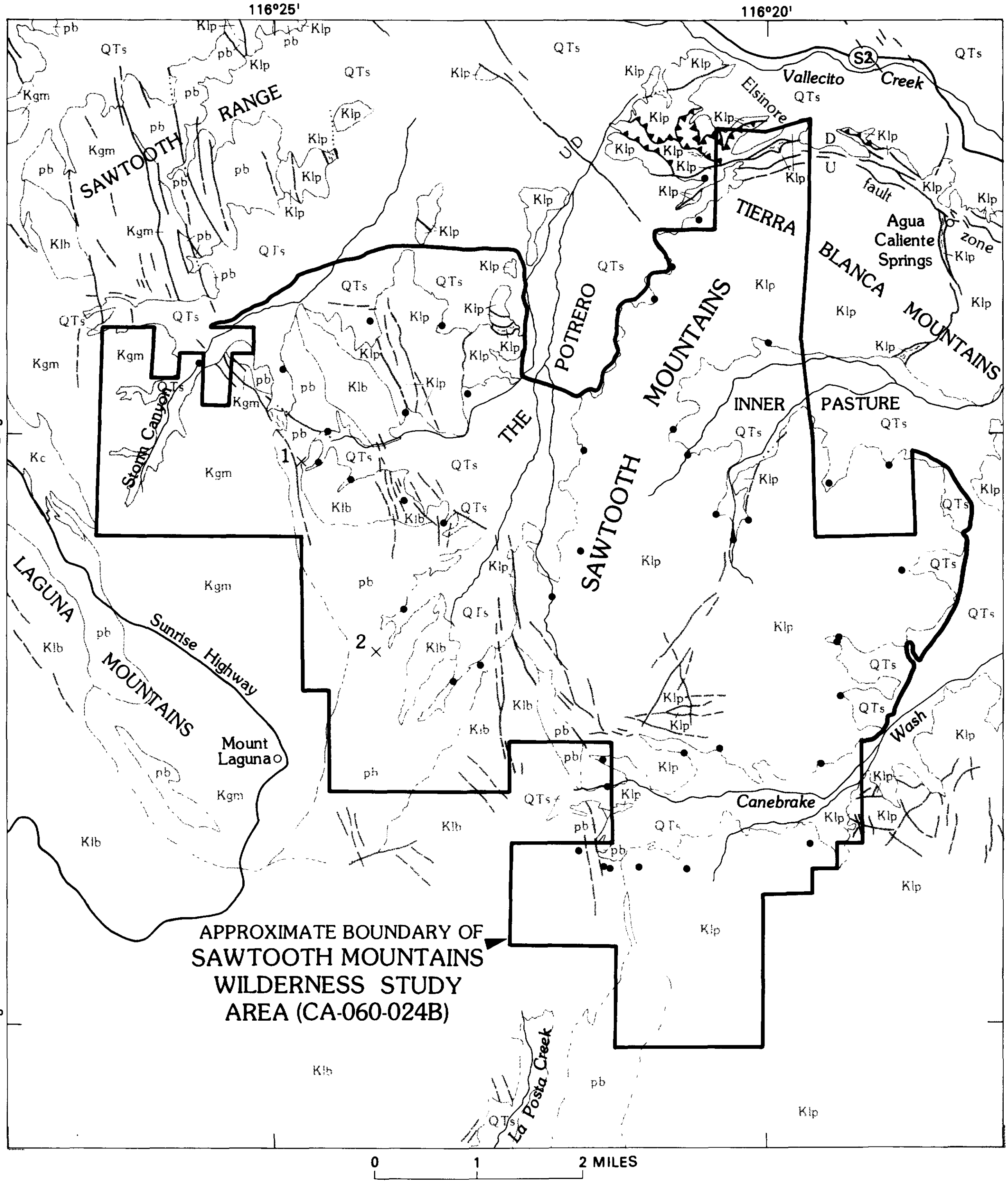


Figure 2. Map showing generalized geology of the Sawtooth Mountains Wilderness Study Area, San Diego County, California. Area contains no mineral or energy resource potential.

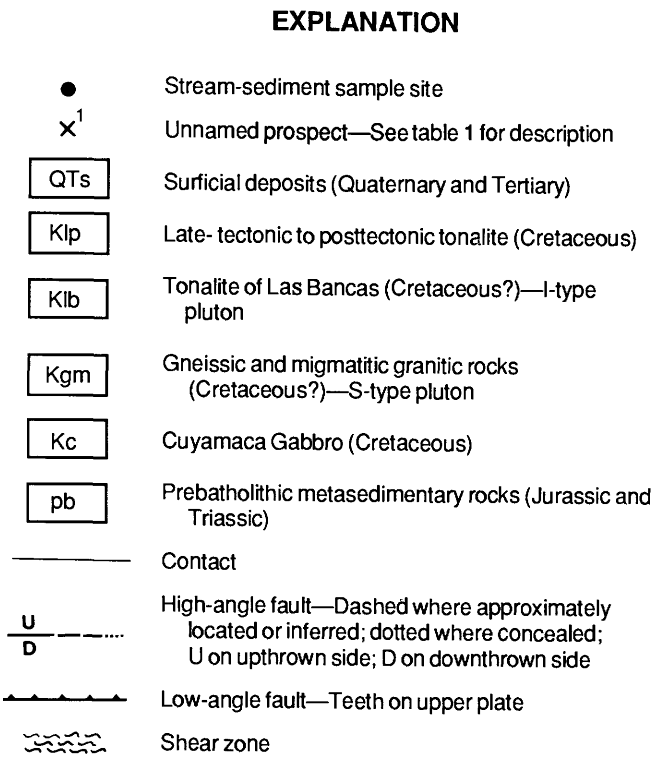


Figure 2. Continued.

Management (BLM) study areas are discussed by Beikman and others (1983). Mineral assessment methodology and terminology are discussed by Goudarzi (1984). Studies by the USGS are designed to provide a reasonable scientific basis for estimating the possibilities for the existence of undiscovered mineral resources by determining geologic units and structures, possible environments of mineral deposition, and presence of geochemical and geophysical anomalies. The USBM evaluates identified resources at individual mines and known mineralized areas by collecting data on current and past mining activites and through field examination of mines, prospects, and mineralized areas.

Published geologic maps of the Agua Caliente Springs (Todd, 1977), Monument Peak (Todd, 1978), and Mount Laguna (Todd, 1979) quadrangles describe the geology of most of the Sawtooth Mountains Wilderness Study Area. The northern part of the Carrizo Gorge/Eastern McCain Valley Wilderness Study Area was mapped by Hoggatt (1979), and a study by Minch and Abbott (1973) provided information on the post-batholithic geologic history south of the study area. The U.S. Geological Survey carried out field investigations in the study areas during 1983 and 1984. The work included new mapping, whole rock and stream sediment sampling for geochemical analysis and radiometric dating, and aeromagnetic and gravity surveys. A total of 98 panned heavy-mineral concentrates from stream sediment samples from both study areas were analyzed. The analytical data are given in Detra and Kilburn (1985a, b).

The U.S. Bureau of Mines conducted a library search for information on mines and prospects in and adjacent to the study areas. These data were supplemented by information from claim owners and from San Diego County and U.S. Bureau of Land Management mining claim and lease records. Field studies by U.S. Bureau of Mines personnel were carried out in 1983. The study areas were searched on foot and by helicopter for evidence of mining activity or mineralized zones. During this time, 13 lode samples were collected from the two study areas for chemical analysis by fire assay, atomic absorption, inductively coupled plasma spectrographic, colorimetric, and X-ray fluorescence methods. In addition, approximately 40 elements were analyzed by semiquantitative spectrographic method. Analytical results are given in Cather (1984) and Lipton (1985).

Acknowledgments

The authors acknowledge Fred Stevens and Loren Beebe who supplied production data pertinent to their mining claims adjacent to the Carrizo Gorge/Eastern McCain Valley Wilderness Study Area. We also thank personnel of the El Centro and Riverside district offices of the Bureau of Land Management for advice on access to the study areas and for generously making their records available to us. The Anza-Borrego Desert State Park gave permission for helicopter landings in the state park adjacent to the study areas.

Regional Geologic Setting

The Sawtooth Mountains and Carrizo Gorge/Eastern McCain Valley Wilderness Study Areas lie within the Cretaceous Peninsular Ranges batholith of southern California, U.S.A., and Baja California, Mexico, and have similar geologic settings. In San Diego County, the batholith is overlapped by Upper Cretaceous to lower Pleistocene(?) sedimentary rocks.

Batholithic rocks in San Diego County have been divided into an older intrusive sequence that was contemporaneous with regional deformation and a younger sequence that largely postdated regional deformation (Todd and Shaw, 1979). Uranium-lead zircon ages from rocks that are considered to belong to the older sequence range from 120 to 105 Ma, whereas ages of the younger plutons range from 100 to 95 Ma (Silver and others, 1979; Clinkenbeard and others, 1986). The older, deformed intrusive sequence was further subdivided into western I-type and eastern S-type granitic rocks (Todd and Shaw, 1979; 1985). This contrast in plutonic rock types is thought to reflect profound west-to-east differences in the source rocks of the batholith: western I-type plutons crystallized from partial melts of igneous source materials and eastern S-type plutons from partial melts of metasedimentary materials. The I- and S-type granitic rock classification is used in this report because it permits a large number of plutons to be divided into two groups, each including genetically related plutons. In San Diego County, these groups appear to be related to the presence or absence of mineral deposits, for example, S-type plutons are locally associated with gold in syntectonic quartz veins (Donnelly, 1934), while I-type granitic plutons show little mineralization.

TABLE 1. *Prospects in the Sawtooth Mountains Wilderness Study Area*

Map No. (fig. 2)	Name	Summary	Workings	Sample data and resource estimate
1	Unnamed prospect	A limonite-stained quartz vein in schist. Vein averages 1.0 ft thick, strikes N. 30° E. and dips steeply. It can be traced about 25 ft along strike.	One shallow prospect pit	One sample of vein contained no significant metal values.
2	Unnamed prospect	A pegmatite dike and accompanying quartz vein are concordant with foliation of biotite schist and strike N. 15° E. and dip 72° SE. Strike length could not be determined due to poor exposure. Pegmatite is about 1.7 ft thick and quartz vein averages 1.0 ft thick and is locally vuggy and limonite-stained. A 4-ft diameter mass of silicified limonite-stained quartzite is within 50 ft of decline.	One 40-ft decline	Three samples collected: a sample from 200-lb stockpile of pegmatite contained 0.03 oz/ton gold; two samples of pegmatite and vein quartz contained no significant metal values.

Prebatholithic rocks that form the western wall of the Peninsular Ranges batholith are composed of metamorphosed volcanic and volcaniclastic rocks of Late Jurassic and Early Cretaceous age (Silver and others, 1963; Fife and others, 1967; Gastil and others, 1975; Schoellhamer and others, 1981). Inclusions of metavolcanic rocks in the batholith in the western part of San Diego County are undated, but are generally correlated with the Upper Jurassic and Lower Cretaceous wallrocks. Wallrock inclusions in eastern San Diego County are composed of metasedimentary rocks that contain minor metavolcanic layers. Possibly related metasedimentary rocks outside the study area have yielded Middle Jurassic, probable Triassic, and Early Ordovician fossils (Gastil and others, 1981; Miller and Dockum, 1983). Although some of the prebatholithic metasedimentary rocks in eastern San Diego County may have been coeval with the western metavolcanic rocks, it is likely that Paleozoic and older Mesozoic strata are present.

Intrusion of the younger plutons, which largely post-dates deformation, was followed by uplift, erosion, sedimentation, and volcanism. Sedimentary and volcanic rocks include the Lusardi Formation, a locally derived continental fanglomerate of Late Cretaceous age, which overlies the eroded batholith in San Diego County (Kennedy and Peterson, 1975), the Eocene Poway Group (Kennedy and Peterson, 1975), and Miocene andesite and basalt (Minch and Abbott, 1973). These volcanic rocks were uplifted by predominantly normal displacements on late Tertiary and Quaternary faults of the Elsinore fault zone, which forms the east margin of the Laguna and In-ko-pah Mountains of the Peninsular Ranges, and these rocks now occupy a position near the crest of the range. Faults of this system are still active, and have displaced batholithic contacts laterally as much as 2 mi (Todd, 1977; 1978; 1979).

APPRAISAL OF IDENTIFIED RESOURCES OF THE SAWTOOTH MOUNTAINS WILDERNESS STUDY AREA

By Eric Cather
U.S. Bureau of Mines

No resources were identified in the Sawtooth Mountains Wilderness Study Area, and no record of mining activity was encountered during the literature search. Two unnamed prospects in the western part of the study area (fig. 2) are in a geologic environment similar to that of mines in the nearby Julian, Deer Park, and Laguna Mountains mining districts, which have yielded gold. Lode gold mines in the Julian district, located 9 mi northwest of the study area, were operated principally from 1870 to the early 1900's, and on a small scale during the 1930's; the mines yielded about $5 million in gold (Weber, 1963). Mineralized zones in the district are primarily in a large inclusion of Triassic and Jurassic(?) metasedimentary rocks that extends to the southeast. These rocks host small gold deposits in the Deer Park and adjacent Laguna Mountains districts about 4 mi west of the study area. The gold in all three districts is found in discontinuous quartz veins that are generally concordant with schistosity.

Four samples were taken at the two unnamed prospects in the study area. A sample of pegmatite from a 200-lb stockpile contained 0.03 oz/ton (troy ounce per ton) gold (table 1). The three remaining samples were from pegmatite and quartz veins and contained no significant metal values (Cather, 1984).

Sand and gravel occurrences in the study area are extensive, but these commodities are more accessible closer to population centers such as San Diego and El Centro. No oil, gas, coal, or geothermal resources were identified in the study area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL OF THE SAWTOOTH MOUNTAINS WILDERNESS STUDY AREA

By Victoria R. Todd, James E. Kilburn, David E. Detra, Andrew Griscom, Daniel H. Knepper, Jr., and Fred A. Kruse
U.S. Geological Survey

Geology

The western half of the Sawtooth Mountains Wilderness Study Area is underlain by Early Cretaceous I- and S-type plutons that were emplaced during regional deformation. I-type plutons consist of pyroxene tonalite and gabbro, while S-type plutons consist of tonalite and granodiorite. Large inclusions of prebatholithic rocks and numerous small inclusions were caught up in, and between, these plutons. All contacts dip steeply to the east. The pervasive north-

northwest fabric of the batholith in the west half of the study area is manifested by the parallel alignment of elongated and flattened plutons, wallrocks, mineral foliation, and the axial planes of isoclinal folds. Lineations and fold axes in both plutons and wallrocks are coaxial and plunge steeply down the dip of foliation. The S-type plutons and wallrocks were folded together into a large south-pointing fold prior to intrusion of the I-type pyroxene tonalite. Moderately deformed pyroxene tonalite apparently intruded the hinge area of the fold and was drawn up north-northwestward along the fold limbs.

The east half of the study area is underlain by part of a large leucocratic tonalite pluton that intruded the I- and S-type plutons; it yields uranium-lead zircon ages of 95, 97, and 98 Ma in the southern part of San Diego County (L.T. Silver, personal commun., 1979; Clinkenbeard and others, 1986). This pluton is moderately deformed along the west margin but is essentially massive in its interior. Swarms of large leucocratic and pegmatite dikes emanate from this pluton and extend for many miles into the older plutonic terrane.

The prebatholithic rocks within and between the plutons consist of calcsilicate-bearing, feldspathic metaquartzite, pelitic schist, minor amphibolite, and scarce marble. The metasedimentary rocks are thin-bedded and contain turbidite structures, suggesting deposition in a deep-water marine marginal basin. Limestone, metamorphosed to marble, is scarce and is found as small lenses. Skarns are present locally where small limestone bodies are intruded by granitic dikes. These prebatholithic rocks are undated but are presumed on regional evidence to be Triassic and Jurassic(?) in age.

Cenozoic deposits in the study area consist of eroded remnants of Pliocene and Pleistocene interfingering marine and continental sedimentary deposits that are overlain by Pleistocene and Holocene alluvial fan deposits on the flanks of the uplifted Laguna and Tierra Blanca Mountains.

At least four episodes of deformation are recorded in the study area. The earliest episode was deep-seated metamorphic folding of the prebatholithic rocks accompanied and followed by intrusion of Early Cretaceous plutons. The second episode involved Late Cretaceous and (or) early Tertiary low-angle faulting at depths of a few miles (Sharp, 1979). Low-angle imbricate faults resulting from this event cut the large pluton in the northeastern part of the study area. During Pleistocene time, sedimentary deposits in the northern part of the study area were folded broadly and eroded. These deposits are cut by the Neogene and Holocene Elsinore fault zone, which crosses the northern part of the study area (Todd, 1977, 1978). Faults in the study area have undergone chiefly dip-slip movement and are not associated with significant alteration.

Geochemical Studies

A reconnaissance geochemical survey of stream sediments was conducted in the Sawtooth Mountains Wilderness Study Area in 1984. Nonmagnetic heavy-mineral concentrates from stream sediments have proven most effective in delineating mineralized systems in the arid environs of the western United States and were accordingly selected as the sample medium for the geochemical survey. Forty-four samples were collected near range fronts from stream beds that drain areas of less than one to several square miles (fig. 2).

The nonmagnetic heavy-mineral concentrate, henceforth referred to as simply the concentrate, is in essence a modified stream sediment. Each sample was composited from active alluvium and sieved through a minus-10-mesh screen to remove the coarsest material. The concentrate was further reduced by bromoform separation and electromagnetic separation and analyzed for 30 elements by a semiquantitative emission spectrographic method (Grimes and Marranzino, 1968). The concentrates were also examined by optical methods to determine the mineral species present in the stream sediments. A complete listing of the analytical results can be found in Detra and Kilburn (1985a).

Geochemical anomalies in the study area were limited to widespread tungsten and tin anomalies in addition to localized silver, barium, copper, bismuth, and lead concentrations. Most concentrates contain scheelite and barite but lack other ore-forming sulfide and oxide minerals. The widespread tin and tungsten anomalies in conjunction with scattered copper, lead, bismuth, and silver concentrations are not surprising. The geologic environment within the study area is similar to that of the large northwest-trending mineralized belt that lies immediately west of the study area (described in an earlier section) in which small skarns are present locally at contacts between metasedimentary rocks and granitic bodies. This belt contains scheelite, gold, and local lead and silver deposits. Considering the substantial amount of scheelite found in the samples from the study area, it would seem reasonable that the area contains scattered tungsten-bearing skarns in which tin, silver, bismuth, copper, and lead may be common constituents. Although no skarn deposits were seen within the study area, undetected small skarn deposits may be present in the series of wallrock screens that underlie steep, brushy slopes along the west side of the study area. The prominent tungsten, copper, and lead anomalies probably originated in these screens. The scattered tungsten anomalies located in the eastern part of the study area, specifically in Canebrake Wash and the Inner Pasture, may be associated with small metasedimentary inclusions within the granitic rocks. Most of the tin probably is derived from an accessory mineral or minerals disseminated throughout the large leucocratic tonalite pluton. Skarns may also have made some contribution to the tin anomalies. Barite, probably derived from minor veins and replacement bodies in the surrounding granitic and metamorphic rocks, was detected in minor amounts in most of the concentrates. Due to the pervasive character of the barite, it is interesting that the only barium anomalies are found near the junction of the Tierra Blanca and Sawtooth Mountains in the northeastern part of the study area. The barium anomalies coincide with the Elsinore fault zone, which may have provided natural conduits for migrating hydrothermal solutions. However, evidence associating the barite and anomalous barium to specific mineralized systems of economic interest is lacking in the study area.

Geophysical Studies

Three aeromagnetic and gamma-ray spectrometer profiles (High Life Helicopters, Inc., and QEB, Inc., 1980) cross the study area with a flightline spacing of approximately 3 mi. The data were collected along east-west traverses by helicopter at a height of 400 ft above ground. The magnetic data collected near the study area are nearly featureless because none of the rocks are particularly magnetic. A major magnetic boundary between magnetic I-type plutonic rocks to the west and nonmagnetic S-type rocks to the east is located 1 to 2 mi west of the study area and there strikes approximately N. 45° W. The radioactivity data for the study area indicate no significant amounts of uranium or thorium.

The limonite mineral group has unique spectral reflectance characteristics that can be detected on Landsat images using a color-ratio compositing technique described by Rowan and others (1974). This technique was applied in the Sawtooth Mountains Wilderness Study Area. The extensive lowland areas along lower Storm Canyon, the Potrero, Inner Pasture, and Canebrake Wash (fig. 2) are densely vegetated and thus could not be evaluated for anomalous concentrations of limonite using Landsat data. Elsewhere in the study area, only a few isolated patches of limonitic materials were observed. These limonitic areas are small and are not clustered into patterns suggestive of possible hydrothermal alteration. The only significant occurrence of anomalous limonite near the study area is in the Tierra Blanca Mountains 1.5 mi northeast of the study area boundary.

Gravity data for the Sawtooth Mountains Wilderness Study Area (Oliver and others, 1980; Roberts and others, 1981; Andrew Griscom, unpub. data, 1986) are sparse and do not provide significant information contributing to a mineral resource appraisal of the study area.

Conclusions

Geologic, geochemical, and geophysical investigations in the Sawtooth Mountains Wilderness Study Area indicate that the area lacks significant mineralization. No mineral resources are identified. Although the geologic setting of the study area is similar to those of the nearby Deer Park and Laguna Mountains mining districts, there is no mineral resource potential for gold or other metals in the study area. This is probably because the host rock for gold-bearing quartz veins, pelitic schist, forms only a minor part of the bedrock in the study area.

Sand and gravel deposits in and near the study area are large, but similar deposits are present closer to population centers. There is no potential for oil, gas, or coal resources in the study area because such commodities would not be expected to occur in crystalline rocks. Hot springs are present at Agua Caliente Springs in the frontal fault zone of the Tierra Blanca Mountains outside the study area, but this locality is not considered a geothermal resource. There are no geothermal resources within the study area.

APPRAISAL OF MINERAL RESOURCES OF THE CARRIZO GORGE/EASTERN McCAIN VALLEY WILDERNESS STUDY AREA

By David A. Lipton
U.S. Bureau of Mines

The Carrizo Gorge/Eastern McCain Valley Wilderness Study Area contains no mines, and no mineral resources were identified in the area. Chemical analyses of nine lode samples from eight properties in and adjacent to the study area by the U.S. Bureau of Mines revealed no anomalous mineral concentrations (table 2) (Lipton, 1985). Two gem-producing mines are adjacent to the west boundary of the study area in the vicinity of Mount Tule (fig. 3). High-grade gem pockets containing kunzite and aquamarine in pegmatite dikes are currently being developed at the Pack Rat and Beebe Hole mines. The Beebe Hole mine has produced gem-quality kunzite valued at approximately $500,000 during the last 10 yr, and aquamarine valued at several thousand dollars in the last few years (Fred Stevens, oral commun., 1984). Additional gem-bearing pockets are likely to exist at these claims, but remaining resources cannot be calculated because of the scattered nature of the deposits.

Pegmatite dikes at these claims dip away from and do not extend into the study area. However, more than two dozen similar pegmatite dikes are present in the area from Mount Tule to Carrizo Gorge and a few dikes are found in the Rockhouse Canyon area. The pegmatite dikes within the study area in the vicinity of Mount Tule contain several of the characteristic minerals used by prospectors to find pockets within the dikes, such as line rock, schorl, and abundant sheets of mica. Detailed exploration of the pegmatite dikes near Mount Tule might disclose gem-bearing pockets. The Rockhouse Canyon area lacks many of the minerals characteristic of gem-bearing pockets.

Small exposures of manganiferous rocks are scattered within the central part of the study area. However, these occurrences are not extensive enough to be considered resources. Occurrences of sand and gravel were not identified. There are no leases for oil and gas or geothermal energy.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL OF THE CARRIZO GORGE/EASTERN McCAIN VALLEY WILDERNESS STUDY AREA

By Victoria R. Todd, James E. Kilburn, David E. Detra, Andrew Griscom, Daniel H. Knepper, Jr., and Fred A. Kruse
U.S. Geological Survey

Geology

The Carrizo Gorge/Eastern McCain Valley Wilderness Study Area is underlain by deformed Early Cretaceous I- and S-type plutonic rocks and prebatholithic metasedimentary rocks (fig. 3). These rocks were intruded by a largely undeformed granitic pluton in part dated at 95 Ma by the uranium-lead method

TABLE 2. *Mines and prospects in and adjacent to the Carrizo Gorge/Eastern McCain Valley Wilderness Study Area*
[*, outside study area]

Map No. (fig. 3)	Name	Summary	Workings and production	Sample data and resource estimate
1	Unnamed prospect	A pegmatite pod 50 by 30 ft in biotite schist has trace amounts of black tourmaline.	One prospect pit 4 ft in diameter.	No samples were taken. No gem minerals were observed.
2	---do---	An intermittent pegmatite dike as thick as 200 ft strikes N. 19° E. and dips vertically in biotite schist. It is probably same dike located at map No. 3. Minor black tourmaline found in pegmatite.	---do---	---do---
3	---do---	An intermittent pegmatite dike as much as 50 ft thick strikes N. 19° E. and dips vertically. Dike is in biotite schist.	One prospect pit 5 ft in diameter.	One random chip sample of pegmatite contained no significant mineral values. No gem minerals were observed.
4	---do---	Manganese oxide-coated schist, gneiss, and phyllite in area of about 20 ft^2.	One prospect pit 4 ft in diameter.	One select sample contained no significant mineral values.
5	---do---	An intermittent quartz vein in quartzite contains manganese oxide as disseminations, blebs 6 in. by 3 in., and surface coatings. The vein is as much as 14 ft thick, trends northeast, and is exposed for approximately 200 ft. Trace fragments of rhodonite present at contact with country rocks.	Four prospect pits each approximately 3 to 6 ft in diameter.	Five chip samples across the vein contained 1.8 pct, 1.3 pct, 1.2 pct, 0.4 pct, and 0.02 pct manganese. A selected sample had 5.3 pct manganese.
6*	Beebe Hole mine	A 12- to 15-ft-thick pegmatite dike strikes N. 22° W. and is exposed intermittently for about 1/2 mi in schist and quartzite. Faulting of dike has caused dip to range from 5° to 60° SW. Pockets within dike have gem minerals of quartz, heliodor, aquamarine, and kunzite. In addition to gem minerals, minor concentrations of lithiophilite, cassiterite, cleavelandite, columbite/tantalite, black tourmaline (schorl), and mica were observed. Most pockets are filled with montmorillonite clay. Pockets range in size from few in. to several ft; three to five pockets commonly in zones.	Three adits, each less than 20 ft long, and one open cut. According to co-partner Fred Stevens, $0.5 million dollars in gem quality kunzite recovered from gem pockets during last 10 years. He further stated that several thousand dollars worth of aquamarine has been recovered during last few years.	It is highly probable that additional gem-bearing pockets will be found on this claim. No samples were taken. Four zones with multiple pockets within the pegmatite were observed to contain small quantities of gem-quality aquamarine, kunzite, and quartz. Although pegmatite dike dips away from, and is outside of, study area, dozens of similar dikes are found on Mount Tule within study area (fig. 3). The similar nature of pegmatite dikes within study area indicates exploration may reveal gem-bearing pockets.
7*	Pack Rat mine	Several 10- to 20-ft-thick pegmatite dikes trend N. 6° W., dip 65° W., and extend as far as one-half mi in schist and quartzite. Pegmatite pockets contain microcline, green mica, black tourmaline (schorl), columbite/tantalite, gem-grade beryl (heliodor), apatite, red garnet (spessartite), and quartz. Most pockets are filled with montmorillonite clay and range in size from few in. to several ft.	Eight open cuts. According to current claimant, several specimens of aquamarine and garnet have been sold.	One random chip sample of green mica contained 6.1 pct potassium, 0.15 pct fluorine, 0.00069 pct beryllium, 0.028 pct lithium, 0.016 pct magnesium, and 0.055 pct manganese. Pockets within pegmatite were observed to contain several indicator minerals of gem-bearing zones. Pegmatite dikes are outside of, and dip away from, study area.
8	Unnamed prospect	Two 15- to 25-ft-thick pegmatite dikes strike north, appear to dip 40° W., and are exposed intermittently for about 1 mi in granite that contains inclusions of schist and quartzite. Pockets in pegmatite contain black tourmaline (schorl), mica, cleavelandite, quartz, and microcline and range in size from few in. to several ft.	Two open cuts	Although no gem minerals were observed, further excavation might yield minerals of grade found at the Pack Rat and Beebe Hole Mines. No samples were taken. Pockets within pegmatite contain several indicator minerals of gem-bearing zones. Pegmatites here are similar to to those worked at the Pack Rat and Beebe Hole mines.

(Clinkenbeard and others, 1986). The study area differs from the Sawtooth Mountains Wilderness Study Area in that the older rocks form a large screen that is surrounded by the undeformed granitic pluton. This pluton consists of tonalite on the west side of the study area and of garnetiferous muscovite-biotite granite in the Jacumba Mountains on the east and south sides of the study area. A steep-walled gabbro-pyroxene tonalite complex, the gabbro-tonalite complex of Mount Tule, underlies Mount Tule in the southwestern part of the study area. This complex includes numerous dikes of the undeformed granitic pluton. A second gabbro-pyroxene tonalite complex is present in the southeast part of the study area. Numerous screens and inclusions of prebatholithic rocks are present within the Mount Tule rocks. Contact relations outside the study area indicate that pyroxene tonalite of the Mount Tule complex intruded the S-type plutonic rocks, which consist of a mixture of S-type gneissic granodiorite, partly melted pelitic schist, and paragneiss. Undeformed garnetiferous two-mica granite in the southern part of the study area has given rise to numerous large leucocratic and pegmatite dikes that extend for miles across the older plutons in the study area.

Upper amphibolite-grade metasedimentary rocks are caught up in both older and younger plutonic rocks in the study area and locally form extensive migmatite zones within the plutonic rocks. These metasedimentary rocks are generally more quartz-rich and, east of the study area, contain more marble than those in the Sawtooth Mountains Wilderness Study Area. Skarns are developed locally where I-type pyroxene tonalite intruded and engulfed marble beds.

A single outcrop of Miocene volcanic rocks, the Alverson Andesite (Dibblee, 1954), is present in the study area. Younger sedimentary deposits northeast of the study area include Pliocene and Pleistocene marine and continental deposits associated with an incursion by the Gulf of California. These deposits are unconformably overlain by Pleistocene and Holocene alluvial fan deposits in Carrizo Canyon to the north,

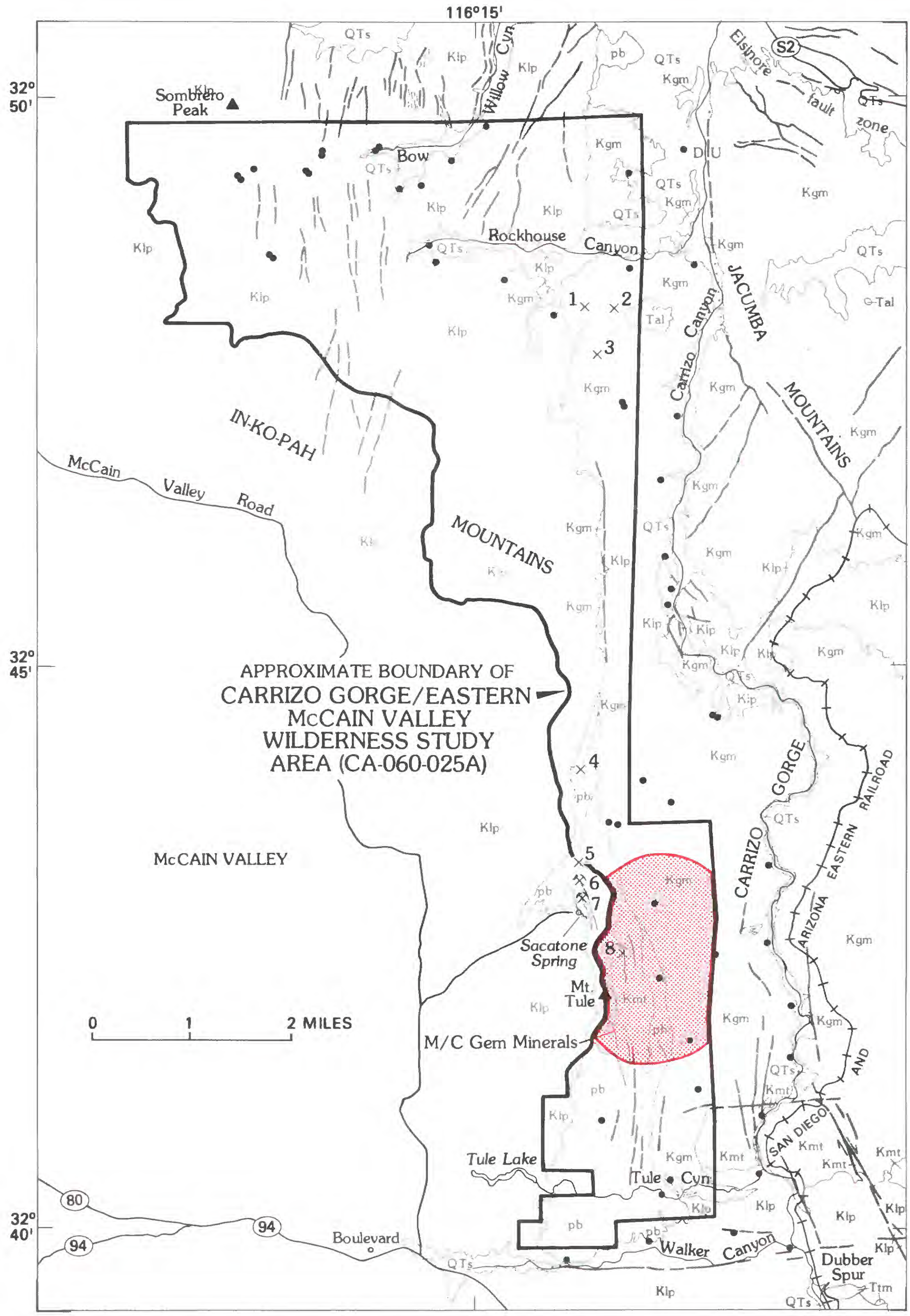


Figure 3. Map showing mineral resource potential and generalized geology of the Carrizo Gorge/ Eastern McCain Valley Wilderness Study Area, San Diego County, California.

EXPLANATION

	Area with moderate mineral resource potential for gem minerals—See appendix for levels of certainty
	Stream-sediment sample site
	Prospect
	Mine with recorded past production—See table 2 for description
1	Unnamed prospect
2	Unnamed prospect
3	Unnamed prospect
4	Unnamed prospect
5	Unnamed prospect
6	Beebe Hole mine
7	Pack Rat mine
8	Unnamed prospect
QTs	Surficial deposits (Quaternary and Tertiary)
Tal	Alverson Andesite of Dibblee (1954) (Miocene)
Ttm	Table Mountain Gravels of Minch and Abbott (1973) (Miocene?)
Klp	Late-tectonic to posttectonic granitic rocks (Cretaceous)
Kmt	Gabbro-tonalite complex of Mount Tule (Cretaceous)—I-type plutons
Kgm	Gneissic and migmatitic granitic rocks (Cretaceous?)—S-type plutons
pb	Prebatholithic metasedimentary rocks (Mesozoic? and Paleozoic?)
	Contact—Dashed where approximately located or inferred
U / D	High-angle fault—Dashed where approximately located or inferred; dotted where concealed. Arrows indicate relative horizontal movement. D, downthrown; U, upthrown
	Shear zone
	Landslide
	Pegmatite dike

Figure 3. Continued.

and by Holocene alluvium in Carrizo Gorge and Walker Canyon east and south, respectively, of the study area.

Faults of the Neogene and Holocene Elsinore fault zone are present in the northern part of the study area. Right-lateral, north- and north-northwest-striking faults in the southern part of the map area have displaced Early Cretaceous plutonic contacts, but the intrusive contact of the undeformed leucocratic granitic pluton is only slightly offset. Faults of this trend continued to be active in Tertiary time because they cut the Jacumba Volcanics south of the study area (Minch and Abbott, 1973). The west-striking Walker Canyon fault may have been active at about the same time.

Geochemical Studies

A reconnaissance geochemical survey of stream sediments was conducted in the Carrizo Gorge/Eastern McCain Valley Wilderness Study Area in 1984. Sampling and analytical methods are described in an earlier section on geochemical investigations in the Sawtooth Mountains Wilderness Study Area. A complete listing of the analytical results can be found in Detra and Kilburn (1985b).

Spectrographic analysis revealed widespread tungsten and tin anomalies as well as locally high concentrations of boron, bismuth, molybdenum, and barium. Mineralogically, the study area is characterized by widespread scheelite and barite and an absence of ore-forming sulfide and oxide minerals. The study area contains numerous pegmatite dikes and skarns that contain the above elements as common constituents. The most prominent tungsten anomalies are present with the only boron and bismuth anomalies in drainages along the east flank of Mount Tule in the southern part of the study area. Locally, minor tin anomalies accompany the boron and tungsten. Molybdenum anomalies are chiefly confined to Carrizo, Rockhouse, and Bow Willow Canyons in the north half of the study area and are also associated with the widespread tin anomalies. Unfortunately, no parent mineral was determined for the tin anomalies, which appear to be a regional trait. Most of the tin anomalies probably come from an accessory mineral, or minerals, in the undeformed leucocratic granitic pluton. Various minerals in skarns and pegmatites may have contributed in some measure to the tin anomalies. Scheelite was identified by optical methods as a minor mineral component in about 80 percent of the concentrates and tourmaline was found coincident with the Mount Tule boron anomalies.

The anomalous barium concentrations found in Rockhouse and Bow Willow Canyons probably represent minor barite veins and (or) replacement bodies in the surrounding metasedimentary and granitic rocks. Barite, identified by optical methods, is present in the majority of the samples but associated ore-related minerals were not located in the study area. Barite formation may be related to circulation of hydrothermal solutions in faults of the Elsinore fault zone.

Geophysical Studies

Four aeromagnetic and gamma-ray spectrometer profiles (High Life Helicopter, Inc., and QEB, Inc., 1980) cross the study area with a flightline spacing of approximately 3 mi. The data were collected along east-west traverses by helicopter at a height of 400 ft above ground. The magnetic data are nearly featureless because none of the rocks within the study area are particularly magnetic. The radioactivity data for these profiles show no anomalous amounts of uranium or thorium within the study area.

The limonite mineral group has unique spectral reflectance characteristics that can be detected on Landsat images using a color-ratio compositing technique described by Rowan and others (1974). This technique was used to look for areas of limonite in the Carrizo Gorge/Eastern McCain Valley Wilderness

Study Area. The spectral response to Landsat data of the study area is dominated by vegetation. Consequently, the presence of anomalous concentrations of limonite that might possibly be associated with hydrothermal alteration could not be evaluated in most of the study area. In the eastern part of the study area, between Carrizo Gorge and the less dissected uplands to the west, the data indicate scattered occurrences of limonitic materials at the surface, but these occurrences are small and are not clustered into patterns that suggest hydrothermal alteration.

Gravity data available for the study area (Oliver and others, 1980; Roberts and others, 1981; Andrew Griscom, unpub. data, 1986) represent only about 10 stations and do not contribute significantly to the mineral resource appraisal of the area.

Conclusions

Geologic studies, geochemical sampling, examination of prospects, and the absence of producing mines in the Carrizo Gorge/Eastern McCain Valley Wilderness Study Area indicate that the area lacks significant mineralization. Gem-bearing pegmatite dikes have been mined for aquamarine and kunzite at two claims outside, and adjacent to, the west boundary of the study area. The host rock of the gem-bearing dikes is a large, predominantly metasedimentary screen near Mount Tule. Although the pegmatite dikes at these claims do not extend into the study area, similar pegmatite dikes are present within the area in the vicinity of Mount Tule. Available data suggest that the Carrizo Gorge/Eastern McCain Valley Wilderness Study Area has moderate potential (certainty level C) for gem-grade minerals in pegmatite dikes in the vicinity of Mount Tule. See appendix for definition of levels of mineral resource potential and certainty of assessment. No other mineral resources are indicated and there is no potential for sand and gravel resources. There is no potential for resources of oil and gas or geothermal energy in the study area because such commodities would not be expected to occur in crystalline rocks.

REFERENCES CITED

Beikman, H.M., Hinkle, M.E., Frieders, Twila, Marcus, S.M., and Edward, J.R., 1983, Mineral surveys by the Geological Survey and the Bureau of Mines of Bureau of Land Management Wilderness Study Areas: U.S. Geological Survey Circular 901, 28 p.

Cather, Eric, 1984, Mineral resources of the Sawtooth Mountains B Wilderness Study Area (BLM No. 060-024B), San Diego County, California: U.S. Bureau of Mines Open-File Report MLA 30-84, 13 p.

Clinkenbeard, J.P., Walawender, M.J., Parrish, K.E., and Wardlaw, M.S., 1986, The geochemical and isotopic composition of the La Posta Granodiorite, San Diego County, California: Geological Society of America Abstracts with Programs, v. 18, no. 2, p. 95.

Detra, D.E., and Kilburn, J.E., 1985a, Analytical results and sample locality maps of heavy-mineral concentrate samples from the Sawtooth Mountains Wilderness Study Area (CA-060-024B), San Diego County, California: U.S. Geological Survey Open-File Report 85-748.

____1985b, Analytical results and sample locality maps of heavy-mineral concentrate samples from the Carrizo Gorge Wilderness Study Area (CA-060-025A), San Diego County, California: U.S. Geological Survey Open-File Report 85-716.

Dibblee, T.W., Jr., 1954, Geology of the Imperial Valley region, California, in Jahns, R.H., ed., Geology of southern California: California Division of Mines Bulletin 170, p. 21-28.

Donnelly, Maurice, 1934, Geology and mineral deposits of the Julian district, San Diego County, California: California Journal of Mines and Geology, v. 30, p. 331-370.

Fife, D.L., Minch, J.A., and Crampton, R.J., 1967, Late Jurassic age of the Santiago Peak Volcanics, California Division of Mines and Geology: Geological Society of America Bulletin, v. 78, p. 299-304.

Gastil, R.G., Morgan, G.J., and Krummenacher, D., 1981, The tectonic history of Peninsular California and adjacent Mexico, in The Geotectonic Development of California, Rubey Volume I, Ernst, W.G., ed., Prentice-Hall, Inc., New Jersey, p. 284-306.

Gastil, R.G., Phillips, R.P., and Allison, E.C., 1975, Reconnaissance geology of the State of Baja California: Geological Society of America Memoir 140, 170 p., 1 sheet.

Goudarzi, G.H., 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84-787, 51 p.

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.

High Life Helicopters, Inc., and QEB, Inc., 1980, Airborne gamma-ray spectrometer and magnetometer survey, San Diego quadrangle, California (1° by 2° sheet; National Uranium Resource Evaluation program, GJBX (80)): Grand Junction, Colo., U.S. Department of Energy, variously paged.

Hoggatt, W.C., 1979, Geologic map of the Sweeney Pass quadrangle, San Diego County, California: U.S. Geological Survey Open-File Report 79-754, 28 p.

Kennedy, M.P., and Peterson, G.L., 1975, Geology of the eastern San Diego metropolitan area, California: California Division of Mines and Geology Bulletin 200, p. 43-56.

Lipton, D.A., 1985, Mineral resources of the Carrizo Gorge Wilderness Study Area (BLM No. CA-060-025A), San Diego County, California: U.S. Bureau of Mines Open-File Report MLA 23-85, 14 p.

Miller, R.H., and Dockum, M.S., 1983, Ordovician conodonts from metamorphosed carbonates of the Salton Trough, California: Geology, v. 11, p. 410-412.

Minch, J.A., and Abbott, P.L., 1973, Post batholithic geology of the Jacumba area, southeastern San Diego County, California: San Diego Society of Natural History, Transactions, v. 17, no. 11, p. 129-135.

Oliver, H.W., Chapman, R.H., Biehler, S., Robbins, S.L., Hanna, W.F., Griscom, Andrew, Beyer, L.A., and Silver, E.A., 1980, Gravity map of California and its continental margin: California Division of Mines and Geology, scale 1:750,000, 2 sheets.

Roberts, C.W., Jachens, R.C., and Oliver, H.W., 1981, Preliminary isostatic residual gravity map of California: U.S. Geological Survey Open-File Report 81-573, scale 1:750,000, 5 sheets.

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.

Schoellhamer, J.E., Vedder, J.G., Yerkes R.F., and Kinney, D.M., 1981, Geology of the northern Santa Ana Mountains, California: U.S. Geological Survey Professional Paper 420-D, 109 p.

Sharp, R.V., 1979, Some characteristics of the eastern Peninsular Ranges mylonite zone, in Proceedings, Conference VIII, analysis of actual fault zones in bedrock: U.S. Geological Survey Open-File Report 79-1239, p. 258-267.

Silver, L.T., Stehli, F.G., and Allen, C.R., 1963, Lower Cretaceous prebatholithic rocks of northern Baja California, Mexico: American Association of Petroleum Geologists Bulletin, v. 47, p. 2054-2059.

Silver, L.T., Taylor, H.P., Jr., and Chappell, B., 1979, Some petrological, geochemical, and geochronological observations of the Peninsular Ranges batholith near the International Border of the U.S.A., and Mexico, in Abbott, P.L., and Todd, V.R., eds., Mesozoic Crystalline Rocks: Guidebook for Geological Society of America Annual Meeting, San Diego, California, p. 83-110.

Todd, V.R., 1977, Geologic map of the Agua Caliente Springs quadrangle, San Diego County, California: U.S. Geological Survey Open-File Report 77-742.

______1978, Geologic map of the Monument Peak quadrangle, San Diego County, California: U.S. Geological Survey Open-File Report 78-697.

______1979, Geologic map of the Mount Laguna quadrangle, San Diego County, California: U.S. Geological Survey Open-File Report 79-862.

Todd, V.R., and Shaw, S.E., 1979, Structural, metamorphic and intrusive framework of the Peninsular Ranges batholith in southern San Diego County, California, in Abbott, P.L., and Todd, V.R., eds., Mesozoic Crystalline Rocks: Guidebook for Geological Society of America Annual Meeting, San Diego, California, p. 177-231.

______1985, S-type granitoids and an I-S line in the Peninsular Ranges batholith, southern California: Geology, v. 13, p. 231-233.

Weber, F.H., 1963, Geology and mineral resources of San Diego County, California: California Division of Mines and Geology, County Report 3, 109 p.

APPENDIX. Definition of levels of mineral resource potential and certainty of assessment

Definitions of Mineral Resource Potential

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

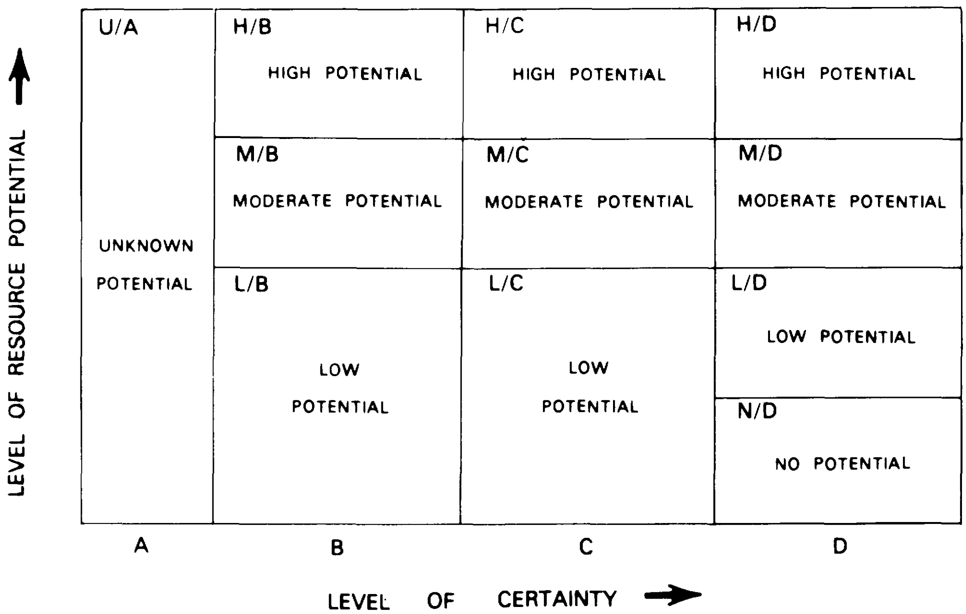
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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

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

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

Levels of Certainty



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

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

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

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

GEOLOGIC TIME CHART

Terms and boundary ages used by the U.S. Geological Survey in this report

EON	ERA	PERIOD		EPOCH	AGE ESTIMATES OF BOUNDARIES (in Ma)
Phanerozoic	Cenozoic	Quaternary		Holocene	0.010
				Pleistocene	1.7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late	96
				Early	138
		Jurassic		Late Middle Early	205
		Triassic		Late Middle Early	~240
	Paleozoic	Permian		Late Early	290
		Carboniferous Periods	Pennsylvanian	Late Middle Early	~330
			Mississippian	Late Early	360
		Devonian		Late Middle Early	410
		Silurian		Late Middle Early	435
		Ordovician		Late Middle Early	500
		Cambrian		Late Middle Early	~570[1]
Proterozoic	Late Proterozoic				900
	Middle Proterozoic				1600
	Early Proterozoic				2500
Archean	Late Archean				3000
	Middle Archean				3400
	Early Archean				(3800?)
pre-Archean[2]					4550

[1]Rocks older than 570 Ma also called Precambrian, a time term without specific rank.

[2]Informal time term without specific rank.

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U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849