Mineral Resources of the Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas, San Diego County, California

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Chapter E

Mineral Resources of the Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas, San Diego County, California

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U.S. GEOLOGICAL SURVEY BULLETIN 1711

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
SOUTHERN CALIFORNIA AND CALIFORNIA DESERT CONSERVATION AREA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of mineral surveys for the Southern Otay Mountain (CA-060-029) and Western Otay Mountain (CA-060-028) Wilderness Study Areas, San Diego County, California.

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Mineral Resources of the Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas, San Diego County, California

By Victoria R. Todd, Gregory K. Lee, *and* Howard W. Oliver
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SUMMARY

Abstract

At the request of the U.S. Bureau of Land Management, approximately 7,940 acres of the Southern Otay Mountain Wilderness Study Area (CA-060-029) and 5,750 acres of the Western Otay Mountain Wilderness Study Area (CA-060-028) were evaluated for identified mineral resources (known) and mineral resource potential (undiscovered); any mention of the study areas in this report refers only to those areas for which mineral surveys were made. The study areas, in southwest San Diego County, Calif., are contiguous and have similar geology and mineral resources. Several mines, prospects, and claims are present in the study areas, but none are being actively mined; only one, the Border View claims, is being actively prospected. No mineral resources were identified in the Southern Otay Mountain or Western Otay Mountain Wilderness Study Areas. An area in the northeastern part of the Southern Otay Mountain Wilderness Study Area has low potential for undiscovered gold resources, and the northwestern part of the Western Otay Mountain Wilderness Study Area has low potential for undiscovered gold and lead resources. There is no potential for oil, gas, coal, or geothermal resources in the study areas.

Character and Setting

The Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas are located in the rugged San Ysidro Mountains only 13 to 21 mi inland from the Pacific Ocean (fig. 1). Maximum relief in the southern and western study areas is about 3,150 and 2,800 ft, respectively. The United States-Mexico border forms the south boundary of the Southern Otay Mountain Wilderness Study Area. The areas have a mild, semiarid climate and a dense cover of chapparal.

The study areas are underlain by the Santiago Peak Volcanics of Late Jurassic age (see appendixes for geologic time chart), which are part of a northwest-trending belt of Upper Jurassic and Lower Cretaceous volcanic and sedimentary rocks that extends for at least 400 mi from southern California, U.S.A., down the peninsula of Baja California, Mexico. These rocks were intruded on the east by the Peninsular Ranges batholith of Cretaceous age and are overlain unconformably on the west by Tertiary and Quaternary sedimentary deposits.

Identified Mineral Resources

No mineral resources were identified in the Southern Otay Mountain or Western Otay Mountain Wilderness Study Areas. Gold was found in the 19th century in the Mine Canyon area of the Dulzura (Oneida) mining district adjacent to the east boundary of the Southern Otay Mountain Wilderness Study Area (fig. 2). Production from mines and claims in the Mine Canyon area outside the study area was minor; none of the properties are presently active. Gold was detected in minor amounts in rock samples from six of eight prospects within, or near the boundary of, the study area.

There has been no mining activity in the Western Otay Mountain Wilderness Study Area. The Cedar Creek deposit, which contains sphalerite and galena, lies about 1 mi east of the northeast boundary of the study area. Samples from three prospects within the study area contained no significant metallic or nonmetallic values.

Publication authorized by the Director, U.S. Geological Survey, Feb. 25, 1988.

Mineral Resource Potential of the Southern Otay Mountain Wilderness Study Area

Geologic, geochemical, and geophysical studies indicate low potential for undiscovered gold resources in the northeast part of the study area (fig. 2). Volcanic rocks of Late Jurassic age in the study area underwent low-grade metamorphism and hydrothermal alteration marked by widespread silicification and pyritization, probably during the late stages of emplacement of the Peninsular Ranges batholith during the Cretaceous period. The deposition of gold was localized in and near the Mine Canyon fault. Slightly anomalous concentrations of gold, and other possibly ore-related elements such as silver, tungsten, zinc, antimony, and arsenic, in sediments and rock samples from streams that drain the easternmost part of the study area suggest that small amounts of undiscovered minor precious metals (gold and silver) may be present in that part of the study area. The part of the study area between Mine Canyon and a north-northwest-trending drainage divide about 1 mi to the west has low potential for undiscovered gold resources. There is no potential for oil, gas, coal, or geothermal resources in the study area.

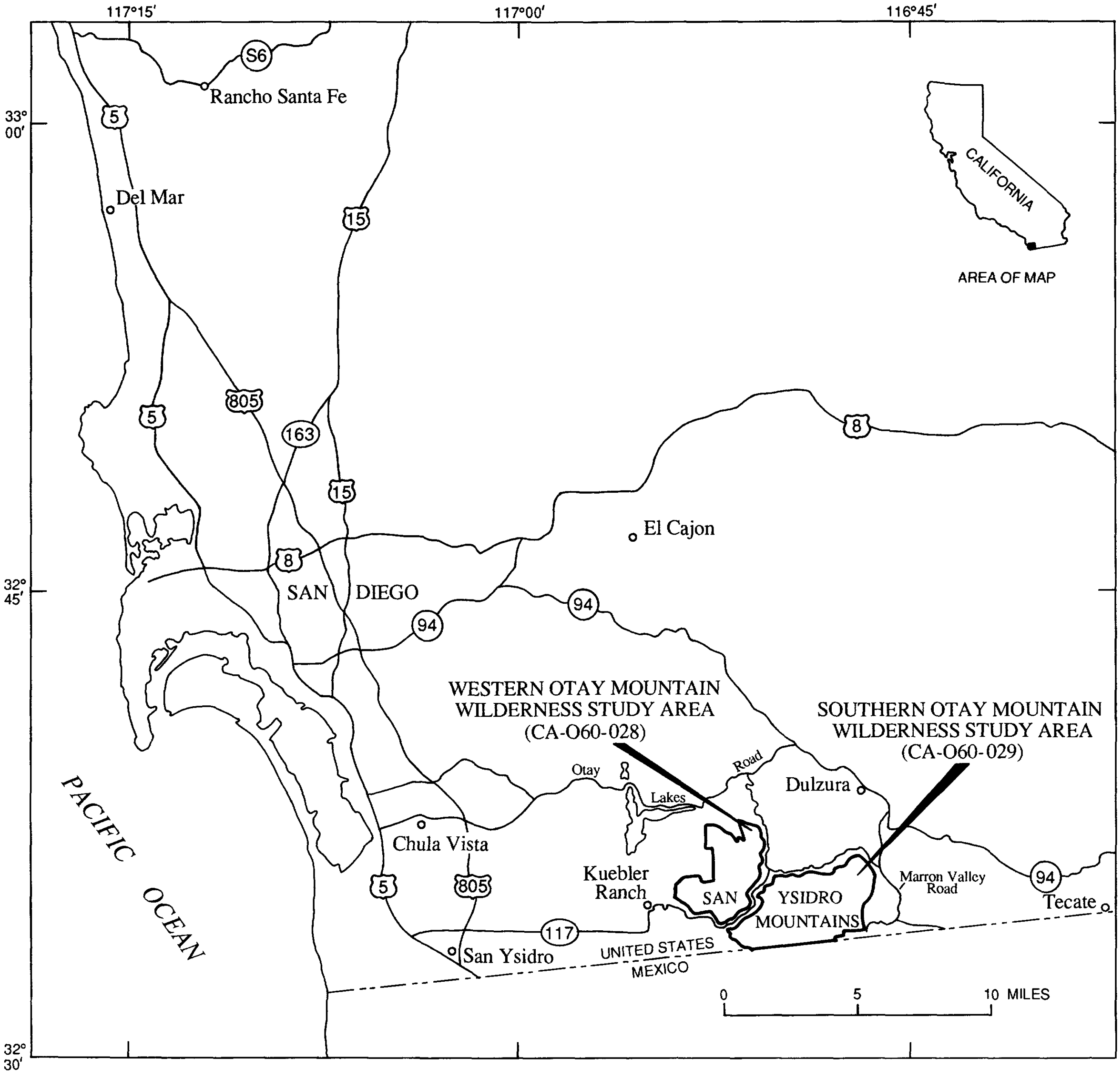


Figure 1. Index map showing location of Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas, San Diego County, California.

Mineral Resource Potential of the Western Otay Mountain Wilderness Study Area

Geochemical studies indicate low potential for undiscovered gold and lead resources in the northwest part of the Western Otay Mountain Wilderness Study Area (fig. 2). Heavy-mineral panned concentrates of sediment from two streams that drain this part of the study area contained detectable gold and anomalous concentrations of lead. There is no potential for oil, gas, coal, or geothermal resources in the study area.

INTRODUCTION

Description of Areas

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

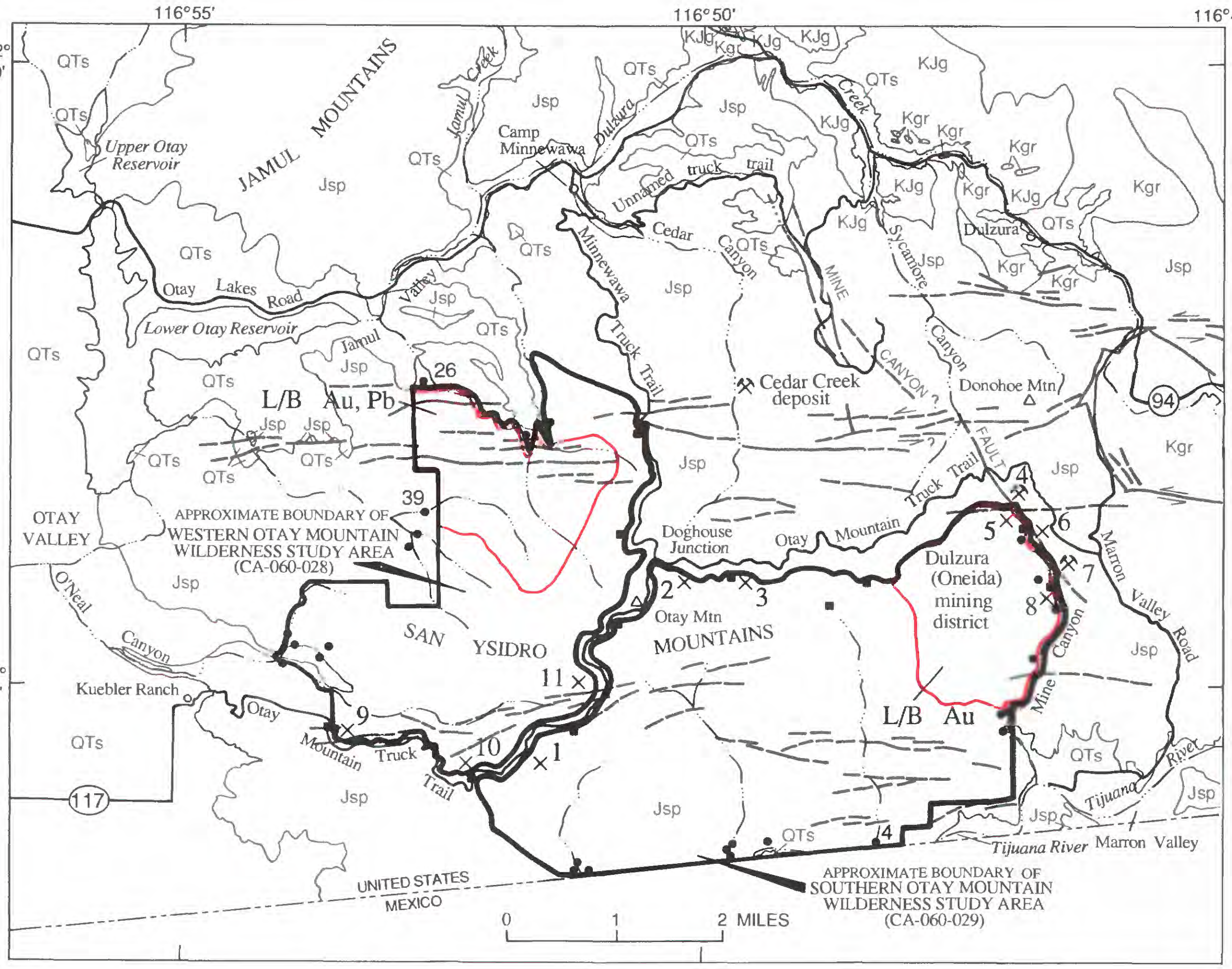
This report presents the results of mineral surveys of the Southern Otay Mountain (CA-060-029) and Western Otay Mountain (CA-060-028) Wilderness Study Areas. The areas studied in the Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas include about 7,940 and 5,750 acres, respectively, in southwest San Diego County, about 20 mi southeast of San Diego (fig. 1). The study areas, separated only by a 1/8-mi-wide strip of land, have similar geology and mineral resources. They are located in the San Ysidro Mountains, a rugged foothill range of the southern California Peninsular Ranges, that lie about 13 to 21 mi inland from the Pacific Ocean. Elevations in the Southern Otay Mountain Wilderness Study Area range from about 400 ft in the Tijuana River valley to 3,551 ft on a peak located south of the Otay Mountain Truck Trail about 1 mi east of its junction with the Minnewawa Truck Trail (fig. 2). In the Western Otay Mountain Wilderness Study Area, elevations range from about 600 ft near Jamul Valley to about 3,400 ft just north of the summit of Otay Mountain (fig. 2). The southern latitude of the San Ysidro Mountains and their proximity to the ocean result in a mild climate with summer daytime temperatures ranging from 80 to 90 °F and average annual precipitation (mainly as rain in the winter) of about 10 in. The mild climate fosters reptilian wildlife and a nearly impenetrable growth of chaparral.

The Southern Otay Mountain Wilderness Study Area is bounded on the north and west by the Otay Mountain Truck Trail, on the south by the Mexican border, and on the east by Mine Canyon and Marron Valley (fig. 2). The Western Otay Mountain Wilderness Study Area is bounded on the east by the Minnewawa Truck Trail, on the southeast and south by the Otay Mountain Truck Trail, and on the west and north by private land. The Otay Mountain Truck Trail lies between the study areas. Access to the study areas is from California State Highway 94 to Marron Valley road, on the east side of the range, and from California State Highway 117 through Kuebler Ranch to the Otay Mountain Truck Trail on the west side (fig. 1). There is a locked gate on Minnewawa Truck Trail at its intersection with the Otay Lakes Road on the north side of the range. Other jeep trails, pack trails, and firebreaks make the study areas accessible by foot.

Previous and Present Investigations

Detailed geologic studies have not been made in the San Ysidro Mountains. Published geologic maps include the San Diego-El Centro 1° x 2° quadrangle by Strand (1962) and the Otay Mesa 7.5' quadrangle by Kennedy and Tan (1977); the latter includes the westernmost part of the San Ysidro Mountains. Weber (1963) briefly described the geology of the San Ysidro Mountains in a report on the mineral resources of San Diego County. The USGS carried out rock and stream-sediment sampling for geochemical analysis in 1985, reconnaissance field mapping in 1986, and aeromagnetic and gravity surveys in 1987. Samples of 25 stream sediments, 22 heavy-mineral panned concentrates, and 22 rocks were collected and analyzed.

The U.S. Bureau of Mines conducted a library search for information on mines and prospects in and near the study areas. Descriptions of mining activity in the Dulzura (Oneida) mining district in and adjacent to the Southern Otay Mountain Wilderness Study Area are found in Storms (1893), Crawford (1896), Merrill (1916), Tucker (1925), and Tucker and Reed (1939). Library research included USBM files and MILS (Mineral Industry Location System). Claim location data were taken from BLM mining claim recordation indices, BLM land status and use



EXPLANATION

Area having low mineral resource potential (L) for commodities as shown; data only suggest certainty level (B)

Commodities

Au — Gold
Pb — Lead

Mines, claims, and prospects—See table 1 for description

1. Unnamed prospect
2. Silver Queen claim
3. Bonanza claim
4. Johnston mine
5. Doolittle group
6. Unnamed prospect
7. Donohoe mine
8. W & T claims
9. Border View Nos. 1-4 claims
10. Ocean View claims
11. Otay Mining Company claim

Description of map units

QTs	Sedimentary deposits (Quaternary and Tertiary)—Includes unnamed fanglomerate deposits, Rosarito Beach Formation, Lindavista Formation, and surficial deposits
Kgr	Undifferentiated granitic rocks (Cretaceous)—Part of Peninsular Ranges batholith
KJg	Gabbro (Cretaceous and(or) Jurassic)—Hypabyssal pluton; may be part of Peninsular Ranges batholith
Jsp	Santiago Peak Volcanics (Jurassic)
	Contact—Dotted where concealed
	High-angle fault—Dashed where approximately located or inferred, dotted where concealed. Arrows indicate sense of lateral displacement, querried where uncertain
	Stream
●26	Stream-sediment sample site—Panned-concentrate and(or) rock samples also taken at some sites. Numbered if noted in text
■	Rock sample site
⚒7	Mine—See table 1 for description
×10	Prospect, claim—See table 1 for description

Figure 2. Mineral resource potential and generalized geology of Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas and vicinity, San Diego County, California. Rock and stream-sediment sample analyses reported by Causey and Schmauch (1987) and G.K. Lee (unpub. data, 1985).

records, and county claim records. In 1986, USBM personnel mapped and sampled workings in and near the study areas and collected 85 rock samples for chemical analysis by fire assay, atomic-absorption, or colorimetric methods. Heavy-mineral separates from two alluvial samples were examined optically. All samples were examined for radioactivity and fluorescence. A summary of analytical results is in Causey and Schmauch (1987); significant results are noted in table 1. Complete results are on file at the USBM, Western Field Operations Center, East 360 Third Avenue, Spokane, WA 99202.

Acknowledgments

The authors thank W.A. Dean of Poway, Calif., for claim information and drill-sample splits. We also thank personnel of the Bureau of Land Management for advice on access to the study areas and for generously making their records available to us.

Regional Geologic Setting

The Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas are underlain by metavolcanic rocks that are assigned to the Upper Jurassic Santiago Peak Volcanics (Larsen, 1948). The Santiago Peak Volcanics are part of a discontinuous, northwest-trending, 10-mi-wide belt of Upper Jurassic and Lower Cretaceous volcanic and sedimentary rocks that lies within a few miles of the Pacific coast and extends for at least 400 mi from southern California, U.S.A., down the peninsula of Baja California, Mexico. These rocks were intruded on the east by the predominantly granitic Peninsular Ranges batholith in Late Jurassic to middle Cretaceous time. They are partly overlain on the west by Upper Cretaceous, Tertiary, and Quaternary sedimentary deposits. Field relations along the length of the volcanic belt suggest that the westernmost, oldest plutons of the batholith were feeders for the overlying volcanic rocks (Todd and others, in press).

Although not studied in detail, the metavolcanic rocks of the San Ysidro Mountains are similar to well-studied volcanic and volcaniclastic sequences elsewhere in San Diego County and northernmost Mexico. Volcanic rocks 35 mi to the northwest near Rancho Santa Fe are andesitic to rhyolitic flows and tuffs with minor basalt (Adams, 1979). Intercalated with these fine-grained rocks are variable amounts of breccia, agglomerate, and volcanic conglomerate composed of clasts of the same volcanic compositions. Balch (1981) and Balch and others (1984) described a sedimentary sequence in the Santiago Peak Volcanics 3 to 6 mi east of Del Mar that includes fossiliferous sandstone, siltstone, and mudstone with sparse tuff layers. Clasts in these rocks are overwhelmingly of volcanic origin, and the sequence contains Late Jurassic marine fossils that were used to date the unit in southern California. Farther to the north, near Camp Pendleton, Buesch (1984) described similar volcanic and volcanic-derived rocks that were intruded by high-level plutons and metamorphosed near the contacts with them. Closer to the wilderness study areas and on strike with the metavolcanic rocks of the San Ysidro Mountains are low-grade metamorphosed andesitic and dacitic tuff and breccia a few mi east of San Diego (Todd, unpublished mapping). Similar rocks also appear about 7 mi south of the Mexican border (Hawkins, 1970).

The Santiago Peak Volcanics are considered to have formed in and near an ancient volcanic archipelago built on oceanic crust close to the Mesozoic western margin of North America (Balch, 1981; Buesch, 1984). The volcanic arc was bordered by deep marine basins that received alternating volcanic eruptions and sediment fans derived from emerging volcanic islands. Soon after eruption and deposition, these accumulations were buried, folded, and thrust faulted(?), probably during an episode of regional deformation that accompanied the earliest intrusions of the Peninsular Ranges batholith. As the result of burial, heating, and local intrusion, the volcanic and sedimentary rocks underwent incipient to low-grade metamorphism. This metamorphism is marked by the development of one or more metamorphic minerals that include chlorite, illite, epidote, albite, calcite, muscovite/sericite, actinolite, serpentine, and stilpnomelane.

APPRAISAL OF IDENTIFIED RESOURCES

By J. Douglas Causey *and* Steven W. Schmauch
U.S. Bureau of Mines

Mines, Prospects, and Mineralized Areas

The first discovery of gold in the region was in 1828 when a small placer deposit was reported at San Ysidro about 10 mi west of the study areas (Browne and Taylor, 1867, p. 13). The earliest confirmed mining activity took place in 1877 when gold was found in the Mine Canyon area (Weber, 1963, p. 63). This area, adjacent to the east boundary of the Southern Otay Mountain Wilderness Study Area is in the Dulzura (Oneida) mining district. Claims located here included the Golden Artery and the Chief of the Hills lode claims. A patent survey of these claims in 1894 reported a 570-ft-long adit, a 100-ft-deep shaft, and several open cuts. The ore averaged \$8 per ton at \$20-per-oz price (Storms, 1893, p. 383). Little additional work was done on the property after it was patented in 1896. This property is now referred to as the Donohoe mine (fig. 2, No. 7).

The Johnston mine and Doolittle group are located northwest of the Donohoe mine, also in Mine Canyon. The Johnston mine was located in the 1890's and includes a 330-ft-long adit and several small pits (fig. 2, No. 4). The Doolittle group was located in the 1930's and has one small pit according to Weber (1963, p. 122 and 143). This group probably also includes a nearby adit (fig. 2, Nos. 5 and 6). Both properties had limited exploration.

About 1/4 mi south of the Donohoe mine in Mine Canyon, 3 oz of gold was recovered from 300 yd^3 of gravel on the Golden Artery placer claims in 1932 (U.S. Bureau of Mines production records).

The most recent claims in the Southern Otay Mountain Wilderness Study Area are the Silver Queen and Bonanza lode claims (fig. 2, Nos. 2, 3) located along the Otay Mountain Truck Trail and the W & T lode claims (fig. 2, No. 8) in Mine Canyon. These claims were located in 1980, 1980, and 1981, respectively. The W & T claims partly cover the Golden Artery placer claims. Except for two old prospect pits and some gravel piles on the W & T, and a small open cut on the Silver Queen, no workings were found on these recent claims.

Three prospects are present in the Western Otay Mountain Wilderness Study Area. The Border View lode claims (fig. 2, No. 9) were located in the 1930's by William Dean's father and relocated in the 1970's by William Dean and Alfred Landry. Assessment work in the 1980's includes trenching, sampling, drilling, and geophysical surveying. The Ocean View and Otay Mining Company claims (fig. 2, Nos. 10, 11) were located by Alfred Landry. All of these claims are southwest of Otay Mountain, along a 4-mi section of the Otay Mountain Truck Trail or the adjacent bulldozed firebreak areas.

Appraisal of Mineral Resources

No mineral resources were identified in the Southern Otay Mountain or Western Otay Mountain Wilderness Study Areas. Descriptions of the properties examined in the study areas and significant analytical results are given in table 1. No property in either study area contained significant gold- or silver-bearing rocks, and no other metallic or industrial mineral commodities were found. Gold-bearing rocks at the Donohoe mine are not known to extend into the study area, but they do parallel the border on the east side of Mine Canyon.

Small-scale recreational placer mining could occur in Mine Canyon on the W & T claims. The gravel deposits here have been worked in the past but still contain a small amount of gold. The gravel is of limited extent, and the gold apparently did not travel far from its source.

No sand and gravel resources were identified in either of the study areas. The occurrences are small and scattered along narrow stream beds.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Victoria R. Todd, Gregory K. Lee, *and* Howard W. Oliver
U.S. Geological Survey

Geology

The Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas are underlain by a sequence of weakly metamorphosed dacitic, andesitic, and rhyolitic volcanic rocks assigned to the Santiago Peak Volcanics. The rocks are resistant, thinly layered to locally massive flows and tuff with minor breccia, agglomerate, and volcanic conglomerate. Sandstone, siltstone, and mudstone form a minor part of the section. Fresh outcrops are typically dark gray to black or greenish gray, weathering to tan and reddish- and yellowish-brown colors due to the oxidation of iron-bearing sulfide minerals. Finely disseminated pyrite is widespread throughout the section, and arsenopyrite is a less common replacement mineral in mineralized rocks (Weber, 1963, p. 124). Parts of the volcanic section have been completely altered to quartz-sericite schist and hornfels. Metamorphic recrystallization and widespread silicification impede the recognition of primary structures; porphyritic and fragmental volcanic textures are fairly common, and flow banding is seen locally. Some felsitic layers grade from silicified metatuff to tuffaceous quartzite and metasiltstone.

Volcanic rocks of the San Ysidro Mountains were intruded on the east by the Cretaceous Peninsular Ranges batholith, which in this region includes undifferentiated granitic rocks and may include gabbro (fig. 2). The gabbro pluton shown in figure 2 is chiefly fine grained and is partly surrounded by the Santiago Peak Volcanics. Because the pluton is undated, it is not known whether it was a feeder for the Late Jurassic volcanic rocks or is part of the Cretaceous Peninsular Ranges batholith. It is possible that high-level plutons such as this one were transitional in age and geologic setting between superjacent volcanic rocks and deeper level plutons of the batholith.

The volcanic rocks in the southern part of the San Ysidro Mountains are cut by fine-grained to aphanitic felsic dikes, possibly related to the emplacement of the batholith. Although the orientations of the dikes vary, the most common trends are northerly and easterly. The dikes appear to have utilized north- and east-trending fractures and faults. Locally, the slight offset of one dike by a second dike of the same set suggests that at least some faulting took place during batholithic emplacement. Quartz veins and stringers occur locally in mineralized zones.

In Otay Valley, the Santiago Peak Volcanics are overlain by Quaternary and Tertiary sedimentary deposits (fig. 2). Tertiary deposits on the western and northwestern

Table 1. Mines, claims, and prospects in and adjacent to the Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas, San Diego County, California

[*, outside wilderness study area]

Map No. (fig. 2)	Name	Summary	Workings and production	Sample data
1	Unnamed prospect.	Greenish-gray metamorphosed dacite(?) in sequence of metamorphosed mudstone, siltstone, and volcanic rocks.	One prospect pit 3 ft by 5 ft by 3 ft deep.	One grab sample contained no significant values.
2	Silver Queen claim.	Metamorphosed volcanic(?) breccia intersected by N. 80° W. shear zone with greenish-gray gouge and 1/2-in.-thick quartz lens.	One prospect pit 20 ft by 135 ft.	Two samples were taken. Chip sample contained no significant values; grab sample had 5 ppb gold.
3	Bonanza claim----	Bleached metavolcanic rocks with minor iron oxide stains adjoin greenish metamorphosed volcanic(?) breccia.	None.	One grab sample contained no significant values.
4	Johnston mine*---	Metavolcanic rocks including dacite or quartz latite with a few small quartz veins are exposed. Northwesterly trending shear zones with steep northeast dips parallel foliation in country rock. Bleaching, silicification, and pyritization prevalent in and near shear zones.	One adit with 330 ft of workings. Two small prospect pits and two shafts.	Twelve chip samples contained from less than 5 to 720 ppb gold. Two samples contained 0.2 and 1.1 ppm silver.
5	Doolittle group----	Intensely silicified dacitic(?) tuff containing minor sericite, opalite, opal, carbonate minerals, and about 1 percent pyrite.	One prospect pit 5 ft by 6 ft by 3 ft deep.	Three random chip samples contained 0.2, 0.8, and 1.1 ppm silver and 20, 45, and 190 ppb gold.
6	Unnamed prospect.*	A 1- to 2-ft-thick shear zone strikes N. 60° E., dips 50° NW, and cuts green hornfels containing fine (1/16 in) disseminated pyrite (up to 2 percent). Quartz crystals line microfractures. Probably rock was originally dacite or andesite tuff.	One 10-ft-long adit.	Two chip samples contained 5 and 10 ppb gold.
7	Donohoe mine* (Chief of the Hills, Golden Artery, Artery Consolidated, Comet, Donohue).	Metamorphosed volcanic rocks including dacite, quartz latite, and rhyolite tuffs. Much of rock is very fine grained quartz sericite schist and hornfels. Fine-grained pyrite is disseminated through much of rock. Foliation strikes about N. 40° W. and dips about 70° NE. No quartz veins are evident.	Four adits, one has 700 ft of drifts, crosscuts, shafts, and stopes; others are 60, 55, and 7 ft long. Five prospect pits, two trenches 23 and 13 ft long, shaft 21 ft deep, millsite foundations, and remnants of dam.	Sixteen chip, twelve grab, and three select samples were taken. Twenty-nine contained between 0.0006 and 0.089 oz/ton gold, and two contained 0.16 and 0.28 oz/ton gold. Ten of these samples contained between 0.02 and 0.64 oz/ton silver, from 3 to 62 ppm copper, 4 to 8 ppm lead, 15 to 650 ppm zinc, and 3 to 18 ppm molybdenum. In seven samples, tungsten ranged from 3 to 5 ppm.
8	W & T claims (incorporates area covered by Golden Artery placer claim).	Massive, jointed, heavily iron oxide stained metamorphosed volcanic rocks. Less than 1 percent pyrite present.	One 8-ft-deep shaft, one small prospect pit, and several sites of worked gravel. Placer production from Golden Artery was 3 oz gold (U.S. Bureau of Mines production records).	Two random chip samples contained 20 ppb gold each. Two placer samples, collected from beneath large boulders, contained 0.0002 and 0.03 oz gold per yd^3
9	Border View Nos. 1-4 claims.	Small, irregularly shaped silicified rhyolite dome in contact with layers of interbedded latite, hornfels, and black flow-banded dacite.	One shaft 23 ft deep, 15 prospect pits, and 3 trenches.	Twenty-two grab samples and five splits from drill-hole cuttings contained no significant values.
10	Ocean View claims.	Light-brown, decomposed metadacite interbedded with hornfels and volcanic breccia.	Two prospect pits and one trench.	Three grab samples contained no significant values.
11	Otay Mining Company claim.	Massive, dark-green, fine-grained metamorphosed tuff. Surfaces weather to light brown.	One prospect pit.	One grab sample contained no significant values.

flanks of the San Ysidro Mountains include the Rosarito Beach Formation (Minch, 1967) and unnamed fanglomerate deposits (Kennedy and Tan, 1977). The Rosarito Beach Formation is described from a section of sedimentary deposits located in northwest Baja California. Lithologically similar deposits that underlie Otay Mesa west of the study area were previously called the Otay Formation or the Otay Member of the Rosarito Beach Formation (Kennedy and Tan, 1977; Pinckney and others, 1979). However, the name Otay Formation or Member has been abandoned north of the border and replaced by Rosarito Beach Formation (Scheidemann and Kuper, 1979). In the vicinity of Otay Mesa, the formation consists mainly of light-colored, poorly indurated, massive sandstone and bentonitic claystone (Kennedy and Tan, 1977). The formation overlies an unnamed boulder-fanglomerate unit that rests unconformably upon the Santiago Peak Volcanics to the east and partly interfingers with the Rosarito Beach Formation to the west. Clasts in this fanglomerate were derived from local bedrock. These Tertiary units are overlain unconformably by the late Pliocene or early Pleistocene nearshore marine and nonmarine Lindavista Formation (Kennedy and Tan, 1977) in Otay Valley and by late Pleistocene and Holocene stream-terrace, slopewash, and alluvial deposits near the Otay Reservoirs and in Jamul and Dulzura Creeks on the northwestern flank of the San Ysidro Mountains. Significant alluvial deposits are also present in Marron Valley, southeast of the Southern Otay Mountain Wilderness Study Area. Alluvial deposits within the study areas occur mainly in the channels of narrow modern streams and are typically thin and discontinuous.

The orientation of layering in the metavolcanic rocks of the San Ysidro Mountains varies considerably from west to east, possibly because of undetected large-scale folds. In the eastern part of the range, layering and foliation trend generally northwest and dip moderately to steeply to the northeast. In the western part, they trend north-northwest to east-northeast and dip gently southwest and north (Kennedy and Tan, 1977).

Faults of two main orientations are present in the San Ysidro Mountains (fig. 2). The northwest-striking Mine Canyon fault in the eastern part of the range parallels the northeast boundary of the Southern Otay Mountain Wilderness Study Area. This fault coincides approximately with the linear array of mines and prospects in the east wall of the upper, northwest-trending part of Mine Canyon (fig. 2). This coincidence suggests that mineralization and faulting are related. Small gouge and breccia zones that generally parallel foliation in the metavolcanic rocks in the Mine Canyon area suggest that the Mine Canyon fault is a bedding-plane fault localized in one or more relatively unresistant, hydrothermally altered felsitic layers. However, geophysical evidence, presented in a later section, suggests that the fault may represent the surficial expression of, or response to, a more significant crustal structure. The Mine Canyon fault coincides closely with northwest-trending gravity and magnetic gradients that continue for at least 12 mi to the northwest (figs. 3 and 4*A*). A magnetic profile across the region (fig. 4*B*) suggests that the contact between the Peninsular Ranges batholith and metavolcanic rocks of the San Ysidro Mountains dips westward and that batholithic rocks are present beneath the rocks of the study area.

Numerous east-trending faults, and possibly fault-related lineaments, cross the range. One of these faults, or fault zones, bisects the Southern Otay Mountain Wilderness Study Area and crosses the southern part of the Western Otay Mountain Wilderness Study Area (fig. 2). A second fault crosses the northern part of the Western Otay Mountain Wilderness Study Area. Numerous east-trending lineaments and felsic dikes occur in the area between the southern fault and the Tijuana River. No mining or prospecting is known to be associated with the east-trending fault zones. East of the San Ysidro Mountains, the partly faulted contact between the Santiago Peak Volcanics and the Peninsular Ranges batholith appears to be offset left laterally 1 to 2 mi on each of three east-striking faults, at least two of which are partly within the map area (fig. 2). One of these faults may cut the Mine Canyon fault, displacing it left laterally as much as 1 mi.

Northwest- and east-striking joints, faults, and megalineaments are common in the Peninsular Ranges batholith and are considered to have formed during the latest stages of emplacement, uplift, and unroofing of the batholith. The above relations suggest that east-trending faulting largely postdates the emplacement of the Cretaceous batholith and the northwest faulting. East-trending faults that cut the sedimentary deposits in the area south of Lower Otay Reservoir (fig. 2) suggest that this faulting was reactivated in the late Tertiary.

The inferred temporal association of faulting, silicification, sericitization, dissemination of sulfides, and gold and silver mineralization in the Mine Canyon area suggests that mineralization took place during low- grade metamorphism and hydrothermal activity accompanying the late stages of emplacement of the batholith. The Mine Canyon fault may be the near-surface expression of a deeper crustal zone of weakness that developed near the contact between the Santiago Peak Volcanics and the Peninsular Ranges batholith. Late-stage fluids from the crystallizing batholith may have utilized this weak zone as a conduit for mineral deposition.

Geochemical Studies

In 1985 a reconnaissance geochemical survey was conducted in the Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas. For the study, 25 stream-sediment, 22 heavy-mineral panned-concentrate, and 22 rock samples were collected and analyzed. Stream-sediment samples were collected from most of the active drainages; at each sample site a composite of fine material from several localities within the stream was collected. In drainages that were large enough to deposit gravel-size sediment, heavy-mineral panned concentrates of stream sediments were also collected. Most rock samples are representative composites of chips from outcrops; at locations where altered rocks were found, the most mineralized or altered material was preferentially collected.

Stream-sediment samples were dried and sieved through an 80-mesh (177-micron) screen, and the fraction finer than 80 mesh was analyzed spectrographically by the method of Crock and others (1987). Panned concentrates were dried, and a small split of each sample was separated for spectrographic analysis using the method of Grimes and Marranzino (1968). The entire remainder of each concentrate was weighed and analyzed for gold content by an atomic-absorption spectrophotometric method as described by Thompson and others (1968). The rock samples were crushed, ground, split, and analyzed by spectrographic, atomic-absorption spectrophotometric, and induction-coupled plasma-atomic emission spectrometric methods (Crock and others, 1987).

Inspection of the statistical distributions of the analytical data and consideration of average crustal abundances of the elements in comparable lithologic terranes (Rose and others, 1979) suggest that at least two vicinities in the study areas contain elevated or anomalous concentrations of several possibly ore-related minerals. Heavy-mineral panned concentrates collected from Mine Canyon and its western tributaries generally contained detectable gold, although at quite low levels (as much as 0.10 parts per million). Visible gold was detected in the concentrates from two of these locations. Slightly elevated silver concentrations were also found at two of the sample sites in this vicinity; tungsten and zinc were each present at single locations in this part of the study area. The presence of accessory ore-related minerals is also indicated by elevated values for antimony and arsenic.

These results indicate at least minor precious-metal (gold and silver) mineralization in the area lying on the west side of Mine Canyon. This mineralization suggests that the northwest-trending faults that apparently control the gold mineralization just east of Mine Canyon in historical mining localities, which include the Donohoe and Johnston mines, may also be present farther to the west. Because no anomalous concentrations of elements were found in samples collected west of Mine Canyon from the next major south-flowing tributary of the Tijuana River (fig. 2, sample No. 4, G.K. Lee, unpub. data, 1985), it seems likely that mineralization is limited to the east side of the drainage divide directly west of the Mine Canyon basin.

A second vicinity that exhibits geochemical evidence of possible mineralization is located in the northwest part of the Western Otay Mountain Wilderness Study Area. Panned-concentrate samples at two locations just downstream from this area (fig. 2, Nos. 26 and 39) contained detectable gold and anomalous lead values as high as 2,000 ppm. Pyrite and galena and possibly anglesite were noted in the concentrate collected at location 26. Slightly elevated copper (100 ppm) and chromium (700 ppm) were also found, although these elements are more likely associated with the syngenetic mineralization of mafic igneous or metaigneous rocks in the area rather than with epigenetic mineralization.

Geophysical Studies

Isostatic gravity residual data and residual total-intensity magnetic data for the San Diego 1° by 2° quadrangle have been compiled by H.W. Oliver and others (unpub. data, 1988). Regional gravity measurements in the San Diego-El Centro area by Biehler (1979) have been recompiled in the vicinity of the Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas (fig. 3). These data have been corrected for effects of elevation, latitude, topography, and regional gradients associated with deep crustal structure. Thus, residual variations in gravity, as indicated by the gravity contours, provide an insight into shallow crustal density variations.

Residual gravity is nearly flat, having a value of about -3 mGal (milligal) over the Santiago Peak Volcanics in the Western Otay Mountain Wilderness Study Area. Farther east, residual gravity rises to a value of +5 mGal at the east edge of the Southern Otay Mountain Wilderness Study Area and reaches a gravity high of +13 mGal over high-density gabbroic rocks about 2 mi northeast of the study area. The maximum horizontal gradient of about 5 to 6 mGal/mi on the west flank of the gravity high nearly coincides with the Mine Canyon fault. This near coincidence indicates that the fault is also the approximate surface projection of a boundary between volcanic rocks having densities of about 2.7 g/cm^3 (grams per cubic centimeter) on the west side and denser (3.0 g/cm^3) gabbroic(?) rocks on the east side. On the basis of this assumed density contrast of +0.3 g/cm^3 and the magnitude of the gravity difference of about 16 mGal, the estimated depth of the gabbro on the northeast side of the fault is about 0.8 mi.

The residual magnetic map and profile (fig. 4) were compiled from sparse low-level (approximately 500 ft above the terrain) airborne data obtained under the National Uranium Resource Evaluation (NURE) program (High Life Helicopters, Inc., and QEB, Inc., 1980; U.S. Department of Energy, written commun., 1985). The profile crosses the Mine Canyon fault about 1 mi north of the study areas (fig. 4). Residual magnetic values range from an ambient level of about -200 nT (nanoteslas) in the vicinity of Lower Otay Reservoir, over the approximate contact between the Santiago Peak Volcanics and relatively thick Tertiary and Quaternary sedimentary deposits to the west, to about +1,300 nT within the two magnetic-high closures that form a magnetic ridge immediately northeast of, and parallel to, the Mine Canyon fault. The magnetic ridge also appears to be associated with the gabbroic rocks and is displaced about 1 mi to the southwest of the gravity high because of the effect of the direction of induced magnetization of these rocks. This direction parallels the Earth's present magnetic field (inclination 61°, declination N. 16° E. in this area).

This magnetic model has been tested quantitatively by transforming the magnetic data to pseudogravity data assuming magnetic induction in the direction of the present field (Baranov, 1957; Blakely and Simpson, 1986). The resulting pseudogravity high derived from the magnetic data is located directly over the +13 mGal gravity high shown in figure 3, and this relation strongly suggests a common source for both anomalies. The source rocks must be the gabbro, which crops out under the gravity and transformed magnetic highs. The near coincidence of the maximum horizontal gradients of both the gravity and pseudogravity fields with the Mine Canyon fault indicates

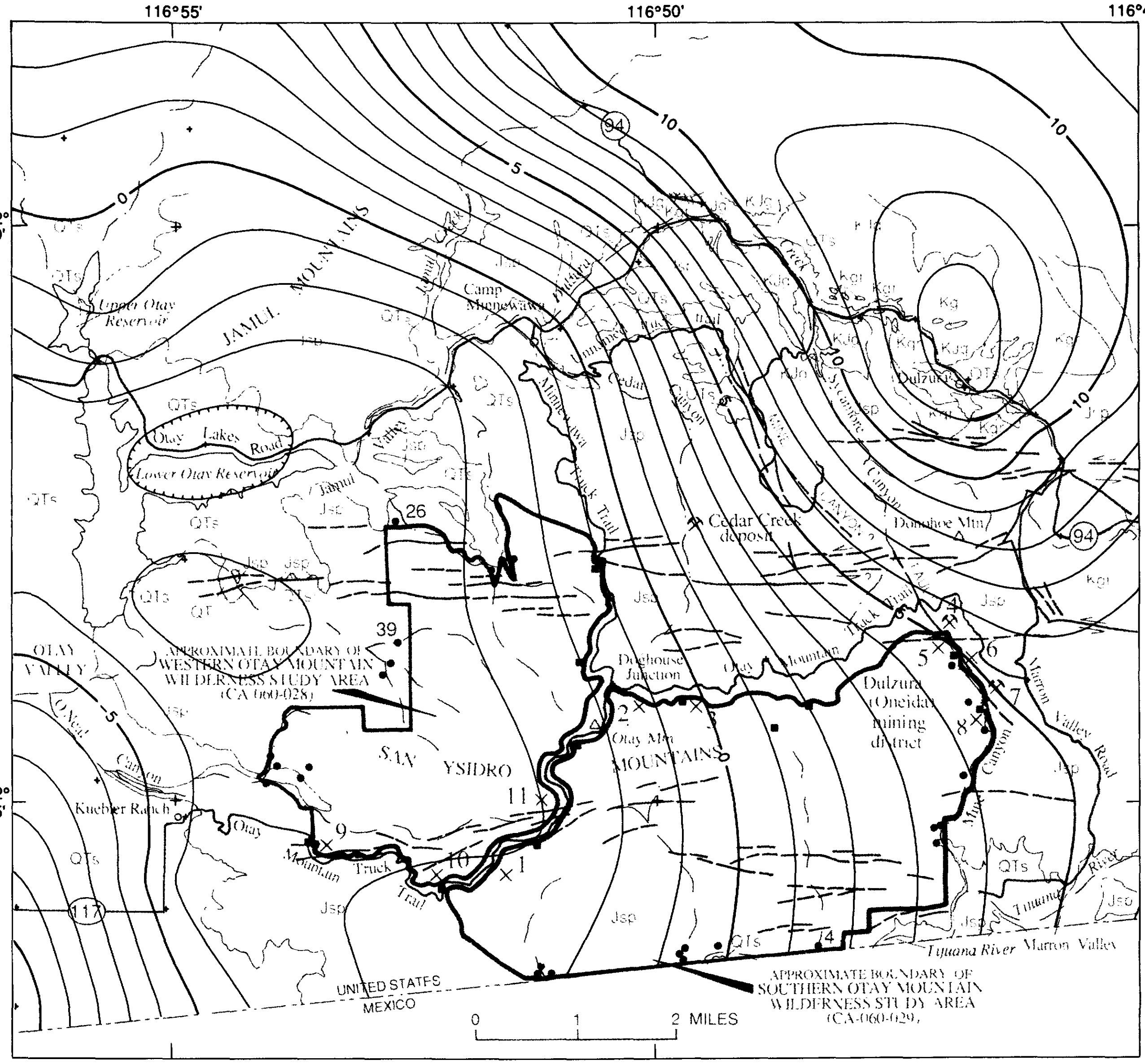


Figure 3. Isostatic gravity residual map of Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas and vicinity, California. Corrected for isostatic and topographic effects; assumed density of 2.67 g/cm³ (grams per cubic centimeter) for rocks above sea level. Isostatic model is Airy type using sea-level crustal thickness of 25 kilometers (15.5 miles) and crust-mantle density contrast of 0.4 g/cm³. Contour interval 1 milligal (mGal); hachures indicate closed area of lower gravity. Gravity stations shown by small crosses. See figure 2 for explanation of geologic units.

that the gabbro probably extends westward under the Santiago Peak Volcanics, at least to the vicinity of the fault, and may be in fault contact with granitic or other less dense, less magnetic rocks at depth on the southwest side of the fault. The relatively gentle slope and 6-mile extent of the flank of the magnetic high west of the Mine Canyon fault (C, fig. 4*B*) also suggest that gabbro, perhaps offset downward on the west side of the fault, extends for some distance to the west of the fault beneath the Santiago Peak Volcanics.

This magnetic interpretation is complicated by the slightly magnetic character of the Santiago Peak Volcanics as evidenced by the magnetic highs marked A and B in figure 4*B*. Magnetic highs are located approximately at the west edge of outcrop of the volcanic rocks (A) and at a topographic ridge in the volcanic rocks (B). The main high, D, located over a small ridge on the east side of Sycamore Canyon (fig. 4*A*), is displaced slightly to the southwest of the gabbro body, as discussed above. The gabbro pluton that crops out east of the study areas is part

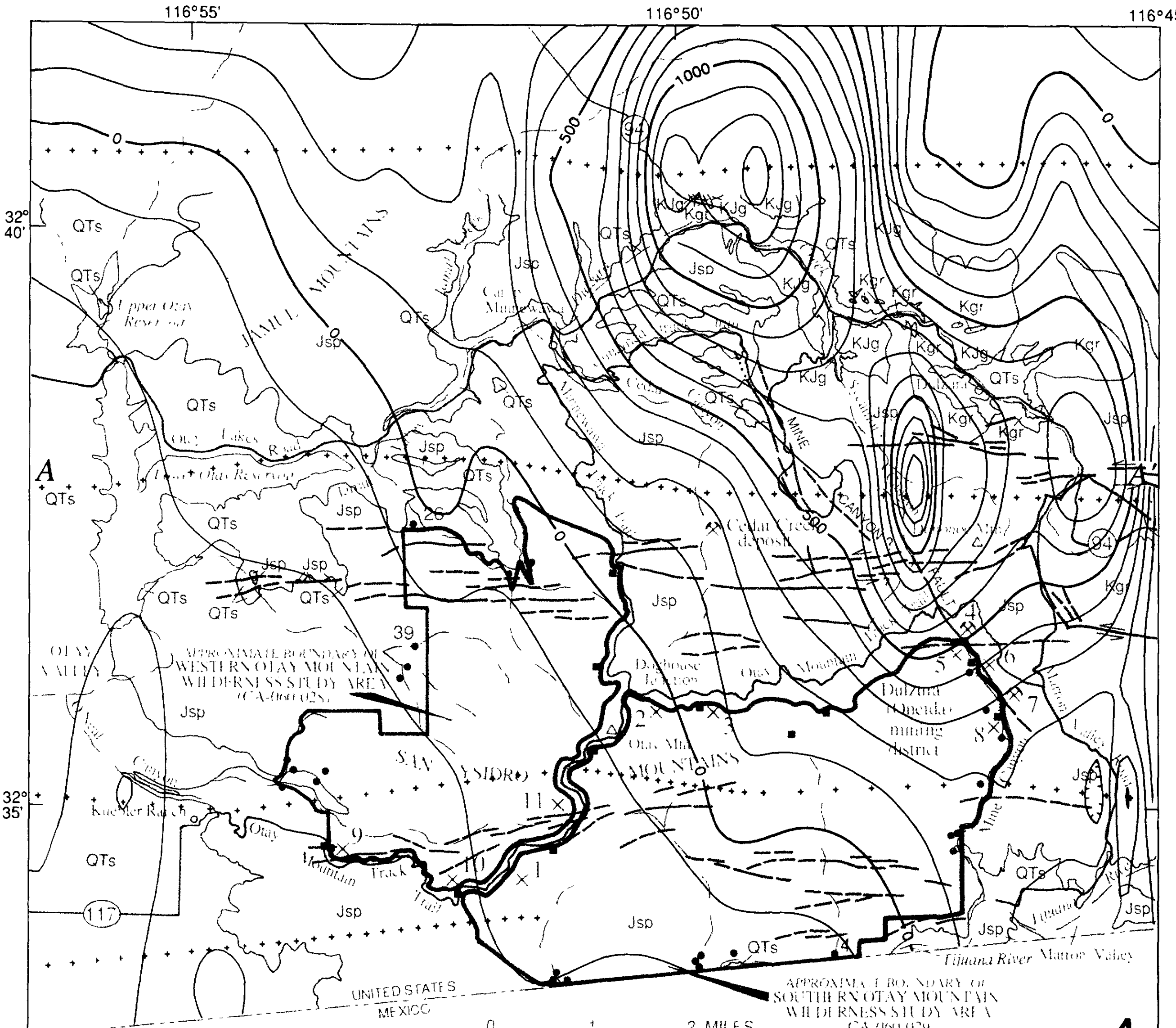


Figure 4. Residual total-intensity aeromagnetic data for Southern Otay Mountain and Western Otay Mountain Wilderness Study Areas and vicinity, San Diego County, California. See figure 2 for explanation of geologic units. *A*, Map of area contoured from 0.3-mile (E-W) by 0.6-mile (N-S) gridded data; contour interval 100 nanoteslas (nT) (1 nT=1 gamma); hachures indicate closed area of lower aeromagnetic intensity. Flightlines shown by small crosses. *B*, Profile *A-A'* along flightline. Details and extremes of profile do not show on map because E-W grid interval of map is coarser than digital readout (3 seconds or about 0.1 mile) along profile.

of a northwest-trending linear array of gabbro plutons that extends for about 20 mi from the Mexican border to El Cajon (fig. 1) near the contact of the Santiago Peak Volcanics and the Peninsular Ranges batholith (Strand, 1962).

Conclusions for the Southern Otay Mountain Wilderness Study Area

Geologic, geochemical, and geophysical investigations in and near the Southern Otay Mountain Wilderness Study Area suggest that the northeastern part of the study area may contain undiscovered gold resources. Historically, mining has been confined largely to the fault in the east wall of Mine Canyon just outside the study area. Slightly anomalous concentrations of gold and other possibly ore-related elements such as silver, tungsten, zinc, antimony, and arsenic in rocks and stream sediments from drainages in the west wall of the canyon suggest that mineralization also took place within the study area. Silicification and pyritization are widespread in the low-grade metavolcanic rocks of the study area, but significant mineralization appears to be confined to the area in and near Mine Canyon. The part of the study area located between Mine Canyon and a prominent north-northwest-trending drainage divide about 1 mi to the west has low potential, certainty level B, for undiscovered gold resources. See appendixes for definition of levels of mineral resource potential and certainty of assessment.

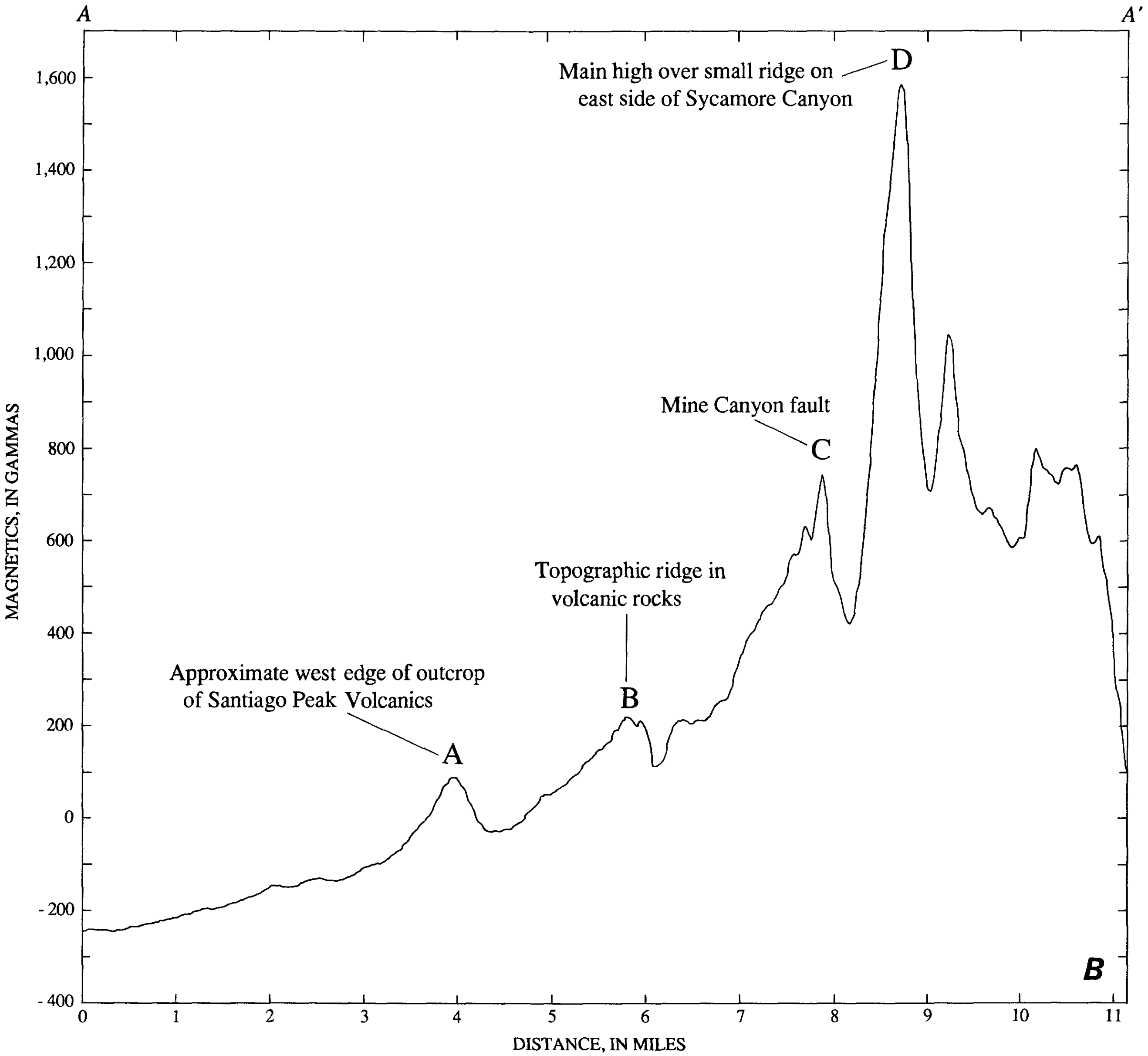


Figure 4. Continued.

There is no potential for oil, gas, coal, or geothermal resources in the study area, certainty level D. None of these resources would be expected to occur in the rock types present in the study areas.

Conclusions for the Western Otay Mountain Wilderness Study Area

The northwestern part of the Western Otay Mountain Wilderness Study Area may have undiscovered gold and lead resources. Heavy-mineral concentrations from two locations in this part of the study area contained detectable gold and high anomalous lead values. Galena and (or) anglesite were also noted in the concentrates collected at one of these sites. Although no lead deposits are known within either of the two study areas, the Cedar Creek deposit (fig. 2), which contains galena with sphalerite, native silver (or silver-bearing galena), and other minerals sparsely distributed in quartz veins (Weber, 1963, p. 173), lies less than 1 mi east of the northeast boundary of the Western Otay Mountain Wilderness Study Area. Three prospects are located in the southern part of the study area, north and west of the Otay Mountain Truck Trail in the O'Neal Canyon drainage. Rock samples from these prospects contained no significant metallic or nonmetallic values. The northwestern part of the Western Otay Mountain Wilderness Study Area is considered to have low potential, certainty level B, for gold and lead resources. No other mineral resources are indicated. There is no potential for oil, gas, coal, or geothermal resources in the study area, certainty level D. None of these resources would be expected to occur in the rock types present in the study area.

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LEVELS OF RESOURCE POTENTIAL

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

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

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

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

U **UNKNOWN** mineral resource potential is assigned to areas where information is inadequate to assign a low, moderate, or high level of resource potential.

LEVELS OF CERTAINTY

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

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

LEVEL OF CERTAINTY →

Abstracted with minor modifications from:

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

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

Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from McKelvey, V.E., 1972, Mineral resource estimates and public policy: American Scientist, v. 60, p. 32-40; and U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, p. 5.

GEOLOGIC TIME CHART

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

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

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

Mineral Resources of Wilderness Study Areas: Southern California and California Desert Conservation Area

This volume was published as chapters A—E

U.S. GEOLOGICAL SURVEY BULLETIN 1711

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

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[Letters designate the separately published chapters]

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