DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

TO ACCOMPANY MAP MF-1606-A

MINERAL RESOURCE POTENTIAL OF THE SUGARLOAF ROADLESS AREA, SAN BERNARDINO COUNTY, CALIFORNIA

SUMMARY REPORT

By

Robert E. Powell, Jonathan C. Matti, Brett F. Cox, Howard W. Oliver, and Alexander Wagini
U. S. Geological Survey

and

Harry W. Campbell
U. S. Bureau of Mines

STUDIES RELATED TO WILDERNESS

Under the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and the Joint Conference Report on Senate Bill 4, 88th Congress, the U. S. Geological Survey and the U. S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System, and some of them are presently being studied. The act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. The act directs that the results of such surveys are to be made available to the public and be submitted to the President and the Congress. This report discusses the results of a mineral survey of the Sugarloaf Roadless Area (05186), San Bernardino National Forest, San Bernardino County, California. The roadless area was classified as a further planning area during the Second Roadless Area Review and Evaluation (RARE II) by the U. S. Forest Service, January 1979.

SUMMARY

Geologic, geochemical, and geophysical investigations and a survey of mines and prospects indicate that the Sugarloaf Roadless Area contains subeconomic graphite and magnesian marble resources. Parts of the area have a low potential for the occurrence of additional low-grade graphite resources, but there is no potential for additional magnesian marble resources within the roadless area. Sand, gravel, and construction stone other than carbonate rocks are found in the roadless area, but similar or better quality materials are abundant and more accessible outside the area. The roadless area has no identified energy mineral resources, but parts of the area have a low to moderate potential for low-grade uranium resources. There are no identified metallic mineral resources within the area, and there is no evidence of a potential for the occurrence of such resources. No previously unknown mineral occurrence was located during this study.

INTRODUCTION

Scope and procedure

This report summarizes the results of geologic, geochemical, and geophysical surveys carried out by the U.S. Geological Survey (R. E. Powell and others, 1982, unpublished map, U.S. Geological Survey, Menlo Park, Calif; Powell and others, 1983; U.S. Geological Survey, 1982) and an investigation of mines, prospects, and mineralized areas conducted by the U.S. Bureau of Mines (Campbell, 1983). These surveys were designed to provide mineral-resource data for land-use decisions regarding the study area and, if compatible with such decisions, to provide a basis from which to plan followup mineral resources investigations. Our objectives in this summary document are (1) to assess known resources[1] in the study area and (2) to evaluate potential for additional resources.

To accomplish the first objective, we have examined known mineral occurrences and reviewed production history of mines and prospects in and around the roadless area, and we have estimated the quantity and quality of known resources where appropriate. To accomplish the second objective, we have sought evidence for mineral concentrations by direct observation (geologic mapping) and by remote techniques (gravity, aeromagnetic, and stream-sediment geochemical surveys). From this evidence and the results of the mining survey, we have identified geologic environments in the study area that are favorable for the concentration of mineral resources and have judged the likelihood (potential) for the presence of undiscovered mineral resources. On the basis of the strength of the available evidence for mineralization, the potential is expressed as low, moderate, or high. Where a specific model can be inferred for the mode of occurrence of known mineral concentrations in the vicinity of the study area, the approximate form and amount of resource (see footnote 1) most likely to be present in any undiscovered mineral deposit is evaluated by appropriate analogy with known deposits.

Geographic setting

The Sugarloaf Roadless Area is located in the central San Bernardino Mountains of San Bernardino County, southern California (fig. 1). The roadless area encompasses about 14 mi^2 (8800 acres) within the San Bernardino National Forest.

---

[1] Resource—a concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible (U.S. Bureau of Mines and U.S. Geological Survey, 1980). Defined in this broad fashion, a resource may include material (reserves) that can be developed profitably under current market conditions or it may contain only material (marginal reserves, subeconomic resources) that requires more favorable market conditions or more advanced technological capability to be developed profitably.

Sugarloaf Mountain (9952 ft), at the center of the area, lies about 6 mi southeast of Big Bear Lake and 21 mi eastnortheast of San Bernardino. From a high (9952 to 8600 ft), arcuate ridge that includes Sugarloaf Mountain, the area drops precipitously northward to about 7800 ft and southward to about 6200 ft. The roadless area is approximately bounded to the south by the Santa Ana River and Cienaga Seca Creek, to the north by Bear Valley, to the east by Green Canyon north of the Sugarloaf Mountain ridge and by Wildhorse Road south of Wildhorse Meadows, and to the west by Staircase Canyon. Major drainages within the area are Wildhorse and Rattlesnake Creeks, two perennial streams that flow southwestward into the Santa Ana River.

The roadless area is readily accessible from the south along State Highway 38, from the north and east along Wildhorse Road, and from the west along Radford Road. Hiking trails maintained by the U.S. Forest Service follow Wildhorse Creek and Green Canyon (USFS trail 2E02) and the Sugarloaf Mountain ridge crest (USFS trail 2E02A). Numerous abandoned logging roads are found along the crest and north flank of the Sugarloaf Mountain ridge.

Geologic setting

The Sugarloaf Roadless Area principally includes Precambrian gneiss, uppermost Precambrian and (or) Paleozoic metamorphosed sedimentary rocks that overlie the gneiss, and Mesozoic plutonic rocks that intrude both the gneiss and the metasedimentary section (fig. 2). The geologic summary presented here is based on field work conducted by Powell, Matti, and Cox in 1981 and 1982, who mapped a study area that extends beyond the boundary of the roadless area. Previous geologic mapping within the area includes that of Vaughan (1922), Dibblee (1964), McJunkin (1976), Cameron (1981,1982), Sadler (1982), and Strathouse (1981, 1982).

Statigraphic units

Three lithologic units comprise a composite gneiss unit beneath the metasedimentary section. The oldest rocks in the study area consist of Precambrian biotite-quartz-feldspar layered gneiss that is probably derived from a sedimentary protolith. This gneiss was intruded by the protolith of a porphyroblastic granodioritic to monzogranitic orthogneiss about 1700 m.y. ago (Silver, 1971). Precambrian(?) mesocratic to leucocratic granitic gneiss also appears to be derived from plutonic rocks that intruded both the metasedimentary gneiss and the orthogneiss. Vaughan (1922) originally included these rocks in the Saragossa Quartzite, but undifferentiated gneiss later was distinguished as Precambrian basement, equivalent to the Baldwin Gneiss of Guillou (1953), beneath unconformably overlying quartzite (Dibblee, 1964; Cameron, 1981; Sadler, 1982).

The Precambrian gneiss is nonconformably overlain by a metamorphosed section of uppermost Precambrian and (or) Paleozoic quartzite, schist, phyllite, and siltite and Paleozoic carbonate rocks. In general, the basal quartzite unit is overlain by the schist, phyllite, and siltite unit that is in turn overlain by the carbonate rocks unit. Locally, however, the schist, phyllite, and siltite unit is tectonically superposed on the Precambrian gneiss. Toward the southeastern limit of its exposure, the schist, phyllite, and siltite unit is complexly interlayered with light-colored, vitreous quartzite; toward the northwestern limit, it is interlayered with carbonate rocks and quartzite. We infer that this complex interlayering is principally structural. We agree with Sadler's (1982) placement of the carbonate rocks unit above all the quartzite and phyllite, rather than Cameron's (1981, 1982) placement of a carbonate rocks unit in a stratigraphically intermediate position between clastic units as well as one above the clastic units.

The lower part of the quartzite unit consists of laminated, light- and dark-gray quartzite; the upper part of the unit consists of vitreous, light-colored quartzite in which bedding commonly is obscure. Aluminous and graphitic phyllite and schist, light- and dark-colored siliceous siltite, and subordinate light-colored, fine-grained quartzite comprise the schist, phyllite, and siltite unit. A slightly discordant layer of greenstone, probably intrusive, locally occurs between vitreous white quartzite and phyllite in the study area. Carbonate rocks consist of generally light-gray crystalline dolomite and magnesian limestone (marble).

Within the study area, generally undeformed mafic and felsic Mesozoic plutonic rocks intrude the Precambrian gneiss and overlying metasedimentary units (Miller and Morton, 1980; Cameron, 1981). Mesozoic plutonic units consist of hornblende and biotite-hornblende gabbro and diorite, sphene-biotite-hornblende monzodiorite and quartz diorite, and biotite monzogranite (igneous-rock nomenclature follows Streckeisen, 1973). The biotite monzogranite, included within the monzodiorite and quartz diorite unit, intrudes both the hornblende gabbro and diorite unit and the monzodiorite and quartz diorite unit. We have not established other sequencing relations among plutonic units within the study area.

Tertiary arkosic sandstone and conglomerate are deposited on crystalline basement in a narrow, discontinuous band south of the Santa Ana fault. The sedimentary rocks constitute part of the Santa Ana Sandstone of Vaughan (1922), as extended by Dibblee (1964), Sadler (1982), and Strathouse (1982). Vesicular olivine-bearing basalt occurs in generally concordant layers within the sandstone, but at some localities it crosscuts bedding within the arkose, indicating the presence of sills and dikes as well as flows. The basalt is late Miocene in age (F. K. Miller, oral commun., 1974; J. L. Morton, oral commun., 1980).

North of the Santa Ana River and south of the Santa Ana fault, erosional remnants of Quaternary alluvial debris are perched on several flat, gently southward-dipping surfaces between incised southwestward-draining tributaries to the Santa Ana River. Additional surfaces, higher up the south flank of Sugarloaf Mountain, are mantled by locally derived alluvial and colluvial debris. Extensive tongues of quartzite talus have been shed down the north and south flanks of the Sugarloaf Mountain ridge.

Faults and folds

A low-angle fault coincides approximately with the nonconformity between Precambrian gneiss and the overlying metasedimentary units of the supracrustal section. One or more additional low-angle faults superpose carbonate rocks on both phyllite and quartzite on the north flank of the Sugarloaf Mountain ridge. These faults are intruded by Mesozoic plutonic units.

At least two generations of folding are necessary to explain the mapped distribution of geologic units within the study area. A major anticline of an older fold set, trending roughly east-west and overturned toward the south, accounts for most of the structural relief between the supracrustal section exposed along the Sugarloaf Mountain ridge crest and remnants of the same section that occur as inclusions in quartz diorite along the Santa Ana River and Cienaga Seca Creek. The distribution of carbonate and clastic rocks on the north flank of Sugarloaf Mountain ridge is controlled in part by parasitic folds on the north limb of this anticline. A syncline of a younger fold set, the axis of which plunges northwest approximately down Green Canyon, has deformed the older fold set and produced an arcuate distribution of geologic units within the mapped area. Parasitic folds within this younger set are overturned toward the northeast.

The ages of the two episodes of folding are not certain. Both generations of folds deform the low-angle faults in the supracrustal section, and may deform Mesozoic plutonic units. Deformed strata in the late Miocene Santa Ana Sandstone, together with its overall map pattern, seem to indicate that it too has been affected by both sets of folds. If this is true, both folding events would have to be at least partly late Cenozoic in age.

The Santa Ana fault trends roughly east-west across the southern part of the study area, dips 60-65° to the north, and exhibits both reverse and left-lateral separation. Crystalline rocks to the north of the Santa Ana fault are juxtaposed against the Santa Ana Sandstone, which rests on crystalline rocks identical to those on the hanging wall. Contacts between quartzite and both Precambrian gneiss and Mesozoic quartz diorite exhibit about 1.5 mi of left-lateral separation.

A northward-dipping normal fault exposed on the south flank of Sugarloaf Mountain (sec. 7, T. 1 N., R. 2 E.) juxtaposes locally derived alluvial deposits on the north against crystalline rocks on the south. The fault is on trend with the physiographic trough of Wildhorse Meadows, and lithologies within the Precambrian gneiss apparently are disrupted along this trend. However, we have found no exposures of the fault other than at the cited locality.

Landslides

Extensive landsliding has occurred throughout the area. Many of the landslides are sufficiently young to be marked by hummocky topography, arcuate troughs with back-facing ridges on the downslope side, and, for some slides, headwall scarps. Other, apparently older, landslides that have subdued or questionable geomorphic expression are identified by chaotic internal structure and by displaced stratigraphic units.

GEOLOGY, GEOCHEMISTRY, AND GEOPHYSICS PERTAINING TO MINERAL RESOURCE ASSESSMENT

Geology

Carbonate rocks occur in the study area along the north flank of the Sugarloaf Mountain ridge and above the confluence of Cienaga Seca Creek and the Santa Ana River. Most of the carbonate rocks are recrystallized magnesian limestone or dolomite (marble).

Graphitic schist occurs in lower Green Canyon between Wildhorse Road and the northern boundary of the roadless area and in the southeastern part of the roadless area near the confluence of Cienaga Seca Creek and the Santa Ana River. It is found in much less abundance at other localities scattered throughout the schist, phyllite, and siltite unit within the roadless area.

Pure quartzite is abundant in the study area along the Sugarloaf Mountain ridge, and plutonic and gneissic construction stone is abundant throughout the southern half of the area. Sand and gravel within the roadless area are generally restricted to small alluvial deposits in narrow mountain stream beds.

The study area includes rocks that were formed and deformed in geologic environments having potential for concentration and deposition of ore minerals by sedimentary, magmatic, metamorphic, and hydrothermal processes. We did not observe concentrations of minerals along any of the faults or intrusive contacts in the roadless area. Nor did we observe significant concentrations of minerals in the Precambrian gneiss or in stratigraphic zones within the metasedimentary units. Although carbonate rocks in the study area are extensively intruded by mafic and intermediate plutonic rocks, we have found no appreciable concentration of skarn minerals. We observed neither prominent veining nor extensive epithermal alteration within the study area, although retrograde metamorphic alteration is pervasive.

Geochemistry

A reconnaissance geochemical survey in the study area was conducted to determine spatial variations in stream-sediment chemistry that might reflect local concentrations of ore minerals: each of 22 stream-sediment samples (fig. 2) was analyzed for 32 elements (Powell and others, 1983). Two bulk-sediment and two heavy-mineral fractions of each sample were analyzed using the semiquantitative emission spectrographic method (Grimes and Marranzino, 1968). The rationale behind a stream-sediment survey is that elements indicative of ore minerals will show up in anomalously high concentrations in drainages that contain deposits of those minerals, in contrast to normal background concentrations in drainages that do not contain deposits. However, because local geochemical anomalies do not necessarily reflect the presence of economic mineral concentrations, the results of a stream-sediment survey must be evaluated within the context of geologic and geophysical data, and conclusions tested with further geochemical studies.

In the bulk-sediment fractions, most of the elements (Fe, Mg, Ca, Ti, Mn, B, Ba, Be, Co, Cu, Cr, La, Nb, Ni, Pb, Sc, Sr, U, V, Y, Zr) were detected in concentrations within an order of magnitude of the ranges of estimated average elemental abundances for the rock-types exposed in the study area (compare, for example, Turekian, 1977; Levinson, 1980, p. 43-44). On the basis of this approximate chemical correspondence between stream sediment and source rock-types, we conclude that none of these elements are anomalous in the bulk-sediment fractions, and that the stream sediment probably contains typical hydraulic accumulations of common rock-forming minerals rather than material that was mechanically or chemically derived from an ore deposit. About a quarter of the elements (As, Au, Bi, Cd, Sb, Sn, W) were not detected in any bulk-sediment fraction. Because the lower detection limit of gold (Au) using the emission spectrographic method is 2,000 times greater than its estimated average elemental abundance for rock-types exposed within the study area, significant gold concentrations in stream sediment derived from gold deposits could remain undetected. Of the remaining elements (Ag, Mo, Th, Zn), silver (Ag) was detected in one of the bulk-sediment fractions of each of two samples (SL-8, 0.5 ppm; SL-13, 0.7 ppm); zinc (Zn) was detected in both bulk-sediment fractions of one sample (SL-20, 200 ppm), and molybdenum (Mo) and thorium (Th) were each detected below their respective nominal lower spectrographic detection limits in one fraction of one sample each (SL-7, Mo less than 5 ppm; SL-13, Th less than 100 ppm).

In the two heavy-mineral fractions, six elements (Ag, As, Au, Bi, Cd, Sb) were not detected in any sample. Four other elements (Co, Cu, Ni, Pb), the ores of which are sulfides, tend to reside with iron (Fe) in paramagnetic minerals rather than to reside in nonmagnetic minerals. This tendency is consistent with the occurrence of these elements in the non-ore ferromagnesian silicates and oxides that we have observed in the rocks of the area, rather than in undiscovered sulfide ore minerals, most of which would contain little or no iron. A slightly elevated concentration of lead (Pb) in the nonmagnetic fraction of one sample (SL-22, 300 ppm) is consistent with the presence of an ore mineral such as galena, but may also indicate roadside contamination.

The distribution of suites of other elements (Fe, Mg, Ca, Ti, Mn, B, Ba, Be, Cr, La, Nb, Sc, Sr, Th, V, Y, Zr) in the two heavy-mineral fractions is generally compatible with the likely distribution and inferred chemical composition of non-ore heavy minerals that we have observed in the rocks of the study area. For example, the greater concentrations of iron, manganese (Mn), chromium (Cr), vanadium (V), and to some extent magnesium (Mg) and titanium (Ti) that we have observed in the total heavy-mineral fraction as compared to the nonmagnetic fraction are consistent with incorporation of these elements in paramagnetic silicate and oxide minerals found in rocks throughout the study area. In another example, calcium (Ca) and magnesium are concentrated in the nonmagnetic heavy-mineral fraction of samples from drainage basins that contain abundant tremolite-bearing metamorphosed carbonate rocks. The remaining elements in the heavy-mineral fractions (Mo, Sn, W, Zn) were detected above their nominal lower spectrographic detection limits in only a few samples each (Mo, 10 ppm in SL-15, -21; Sn, 70 ppm in SL-18, 30 ppm in SL-5, -9, -10, -13, -15, -16, 20 ppm in SL-14; W, 100 ppm in SL-20; Zn, 1,000 ppm in SL-1, 700 ppm in SL-12, 500 ppm in SL-2, -4).

In the heavy-mineral fractions, tin (Sn) and scandium (Sc) were detected in anomalous concentrations in one sample (SL-18). Tungsten (W), detected in the nonmagnetic heavy-mineral fraction of one sample (SL-20), probably occurs in scheelite or wolframite derived from a skarn or quartz vein. In the nonmagnetic heavy-mineral fraction, tin was detected only in samples in which thorium also was detected (SL-5, -9, -10, -13, -14, -15, -16, -17, -18, -21, -22). In addition, other elements (Ca, La, Nb, Sc, Th, Y) are consistently and mutually concentrated in the tin- and thorium-bearing samples as well as in other samples (SL-1, -2, -3, -4).

In the geological setting of the study area, deposits of molybdenum, silver, tin, thorium, tungsten, and zinc could be anticipated in skarns, in hydrothermal veins or stockworks, or otherwise disseminated in zones in plutonic or metasedimentary rocks. The paucity of geologic and prospecting evidence for occurrences of skarn minerals or epithermal alteration, however, together with the low levels of concentration of the cited metals and the absence of coincidentally anomalous concentrations of most trace elements commonly associated with ore minerals of the cited metals, is not compatible with the presence of deposits of these metals.

The association of elements (La, Nb, Sc, Sn, Th, Y) that commonly are partitioned into the melt phase during crystallization of a magma implies a relation to a late-stage plutonic environment, either in minerals that formed late in the crystallization of a pluton, or in volatile-rich magmatic or ore-fluids that migrated outward from the pluton. Preliminary petrographic observations indicate that plutonic rocks with abundant late-crystallizing allanite occur in those drainages from which the thorium-bearing samples were collected, but not in those drainages from which the remaining samples were collected. From these observations, we infer that if the associated elements that are concentrated in the nonmagnetic heavy-mineral fraction are present in a non-ore mineral phase(s) it is probably allanite or associated late-forming heavy minerals, such as zircon. However, because we have not analyzed the chemical composition of the observed minerals, it is possible that these elements are concentrated in unidentified ore-minerals (monazite and cassiterite) that are unevenly distributed in the drainages from which the tin and thorium bearing samples were collected. The uneven distributions might be accommodated by veinlets, seams, or stringers sufficiently small or sparse that we did not observe them in the field. Small monazite-bearing pegmatite veins and biotite-rich stringers within granitic orthogneiss are found near prospects in the Bighorn Mountains about 13 mi northeast of Sugarloaf Mountain (Matti and others, 1982).

Uranium (U) concentrations measured in the minus-80-mesh bulk-sediment fraction of samples from the roadless area appear to be linked with zirconium concentrations, probably in zircon, and do not appear to signal the presence of uranium ore. Although occurrences of uranium ore have been mined and prospected in the Precambrian gneiss in the vicinity of the study area, the highest measured uranium concentration (7.5 ppm, SL-19) is from a drainage basin in which no Precambrian gneiss is mapped, whereas the lowest measured concentration (0.35 ppm, SL-16) is from the drainage basin that contains the Thirsty King uranimum prospect (fig. 2).

In areas of the Transverse Ranges known to have mineral deposits, relatively high concentrations have been detected in the nonmagnetic heavy-mineral fraction of stream-sediment samples for associated suites of elements that include gold (up to 200 ppm), silver (up to 30 ppm), molybdenum (up to 1,500 ppm), tungsten (up to 20,000+ ppm), lead (up to 50,000 ppm), bismuth (Bi, up to 2,000 ppm), tin (up to 2,000 ppm), and thorium (up to 5,000+ ppm) (for references, see Powell and others, 1983). In the context of these elevated values for elements typically associated with mineral deposits in the region, the relatively low concentrations of these elements in samples from the study area provide evidence for a lack of significant mineral concentrations in the Sugarloaf Roadless Area.

Geophysics

Magnetic survey

In an aeromagnetic survey of the Sugarloaf Roadless Area, north-south flight lines about 0.5 mi apart were flown about 1,000 ft above ground (U.S. Geological Survey, 1982). Experience over similar crystalline terrane in central California indicates that these specifications are adequate to reveal significant magnetic iron-ore deposits and to indicate the general location of nickel, chromium, and sulfide deposits associated with magnetite (Oliver, 1982; du Bray and others, 1982).

The aeromagnetic map shows one significant anomaly that is associated with mafic plutonic rocks (hornblende gabbro and diorite unit) exposed on the south flank of Sugarlump in the western part of the roadless area. The anomaly consists of an elliptical high of about 1,900 gammas centered over the south edge of the exposed mafic unit and a broad low of about 200 gammas located to the north of the outcrop. The magnetic low does not wrap around the ends of the magnetic high. Therefore, by using the models presented by Vacquier and others (1951, p. 124-127), we infer that the mafic unit has a thickness that is roughly in the range of one-third to one-half its lateral dimensions.

Using average magnetic susceptibilities of 8 emu (electromagnetic unit)/cm^3 for the hornblende gabbro and diorite unit and 1 emu/cm^3 for the surrounding units, determined from surface samples, we have modeled the configuration of the mafic plutonic unit at depth with a two-dimensional computer program (Saltus and Blakely, 1983). Results of this first-order analysis indicate that the mafic unit extends to a maximum depth of about 8,000 ft below the surface and that its contacts with Precambrian and (or) Paleozoic metasedimentary units and Mesozoic intermediate plutonic rocks dip outward to the north and south. The magnetic survey provides no evidence for iron-enrichment of rocks surrounding the mafic plutonic rocks, a conclusion in agreement with the geologic findings.

Gravity survey

A limited gravity survey of the study area was conducted utilizing elevation control shown on the Moonridge 7 1/2-minute topographic quadrangle (Biehler and others, 1983; see also, Tang and Ponce, 1982). These elevations are considered accurate to ±10 ft, which translates to an uncertainty in gravity anomalies of ±0.6 milligal.

The gravity survey reveals an elliptical gravity high of about 14 milligals centered just north of and overlapping the magnetic high. To test which of the various rock types in the area might cause the anomaly, we measured the density of 30 representative samples. Most samples of the Precambrian gneiss, Precambrian and (or) Paleozoic metasedimentary units, and Mesozoic felsic and intermediate plutonic units in the area have densities of 2.70± 0.05 g/cm^3, but samples of the Mesozoic mafic plutonic rocks have a significantly higher average density of about 3.00± 0.05 g/cm^3.

From these observations, we interpret the gravity high as being caused by the same mafic plutonic unit that produces the 1,900-gamma magnetic high. The magnetic high is offset to the south of the gravity high because of the 60-degree inclination of the earth's magnetic field in this area (Peddie and others, 1976). No other significant gravity anomalies were found in the roadless area.

MINING DISTRICTS AND MINERALIZED AREAS

Methods and previous studies

U. S. Bureau of Mines personnel conducted field work in the vicinity of the Sugarloaf Roadless Area during September 1981 (Campbell, 1983). Sixty-seven lode samples were collected from mines, prospects, and mineralized areas. Descriptions of individual mines and prospects (fig. 2) in the vicinity of the study area are tabulated on the accompanying mineral resource potential map sheet. Previous studies pertaining to mineral deposits in the Sugarloaf study area were conducted by Vaughan (1922), Warne and Reeves (1957a,b), Dibblee (1964), and Rohtert (1979, 1981).

Mining and prospecting history

Early claims in the Sugarloaf Roadless Area were related to the discovery of graphite deposits. The upper and lower St. Francis Graphite prospects are located near the confluence of Cienaga Seca Creek and the Santa Ana River, and the Princes Graphite prospect is located in Green Canyon. Demand for crushed stone, spurred by rapid population growth in the Los Angeles Basin during the 1950's and 1960's, stimulated prospecting of the extensive carbonate rock deposits within the study area. Two prospects in the carbonate rocks unit within the area have been claimed at various times since the 1940's: the Green Canyon quarry on the north flank of Sugarloaf Mountain above Green Canyon and the Sugarloaf Mountain prospect north of Cienaga Seca Creek. A small quantity of crushed magnesian marble from the Green Canyon quarry was marketed as roofing granules in 1960 (Dibblee, 1964, p. 3).

Uranium occurrences in the vicinity of the study area were located in the 1950's when the U.S. Atomic Energy Commission encouraged domestic prospecting to supply nuclear weapons programs: the Thumbum mine in 1953 in May Van Canyon about 1 mi northeast of the roadless area, the Rocky Point (B and B) claims in 1954 about 0.5 mi west of the area, and the Thirsty King claims in 1955 in the southeast corner of the roadless area. The first commercial shipment of uranium from the state of California came from the Thumbum mine in July 1954 (Troxel and others, 1957, p. 671). Building of nuclear reactors has led to renewed interest in uranium prospecting near the study area. Portland General Electric Company and Great Lakes Chemical Corporation were actively exploring for uranium during the late 1970's.

Approximately 340 lode claims have been recorded in or adjacent to the study area; 13 placer claims for carbonate rocks also have been located. There are no patented claims or active mineral leases within the study area.

Graphite

Low-grade graphite in the Sugarloaf area occurs in carbon-rich layers within the uppermost Precambrian and (or) Paleozoic schist, phyllite, and siltite unit at both the upper and lower St. Francis Graphite prospects, and at the Princes Graphite prospect. At these prospects, "amorphous" graphite having a well-developed schistosity has been erroneously reported as flake graphite[2] (Western Prospector, 1973, p. 6). At each prospect, graphitic schist occurs as lenses or layers that pinch and swell and are deformed internally. Graphite deposits at the St. Francis Graphite prospects are in elongate roof pendants in Mesozoic quartz diorite. Graphitic layers a few feet thick can be traced intermittently for nearly 3,000 ft.

Magnesian marble

Magnesian marble constitutes much of the Paleozoic carbonate rocks unit that crops out extensively on the north flank of Sugarloaf Mountain and in roof pendants in Mesozoic quartz diorite north of Cienaga Seca Creek. At the Green Canyon quarry, magnesian marble has an average composition of 36 weight percent calcium oxide (CaO), 11 weight percent magnesian oxide (MgO), 5 weight percent loss on ignition, 4 weight percent silica (SiO_2), 1.5 weight percent iron oxide (Fe_2O_3), and less than 1 weight percent aluminum oxide (Al_2O_3), potash (K_2O), and phosphorous pentoxide (P_2O_5). The chemical composition of magnesian marble at the Sugarloaf Mountain prospect is about 28 weight percent CaO, 14 weight percent MgO, 15 weight percent SiO_2, 2 weight percent Fe_2O_3, 1 weight percent loss on ignition, and less than 1 weight percent Al_2O_3, K_2O, and P_2O_5.

Uranium

Hydrothermal uranium deposits are associated with pegmatite dikes in the Precambrian gneiss. Mineralized zones tend to occur in the upper parts of the dikes near contacts and crosscutting fracture systems (Rohtert, 1981, p. 74). Remobilization of radioactive elements from the primary hydrothermal deposits by ground-water solutions has led to the formation of a supergene uranium deposit at the Thumbum mine.

Gold and silver

Trace concentrations of gold and silver occur in contact zones between carbonate rocks and monzodiorite at the Pashby-Strong prospect just outside the northern boundary of the roadless area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Graphite

Prospects in the Sugarloaf Roadless Area have identified resources of low-grade graphite. The upper St. Francis Graphite prospect contains an estimated 10,000 tons of indicated resources averaging 12 weight percent fixed carbon[3] and 30,000 tons of inferred resources of similar grade. The lower St. Francis Graphite prospect contains an additional 15,000 tons of indicated and 56,000 tons of inferred resources averaging 11 weight percent fixed carbon. The Princes Graphite prospect, which straddles the boundary of the roadless area, contains about 130,000 tons of indicated and 100,000 tons of inferred resources averaging 7 weight percent fixed carbon. Within the roadless area, this prospect contains about 100,000 tons of indicated and 63,000 tons of inferred resources.

There has been no domestic production of natural graphite since 1980. Most imports of amorphous graphite have come from deposits near Sonora, Mexico that are sufficiently high-grade (greater than 85 weight percent graphite) that concentration is unnecessary. Because most uses of amorphous graphite require costly up-grading to about 90 weight percent graphite, low-grade graphite prospects in the study area cannot compete with imported graphite. Therefore, the indicated and inferred graphite resources of the study area are currently subeconomic. The graphite resources at these prospects are close to paved roads and could easily be developed by open pit methods if outside supplies were cut off or exhausted. Although we have found significant quantities of graphitic schist only near the three prospects, because of the structural complexity of the area, we assign a low potential for the presence of low-grade graphite deposits in the subsurface wherever schist is exposed.

Magnesian marble

Identified resources of magnesian marble are abundant at prospects within carbonate rocks in the Sugarloaf Roadless Area. The Green Canyon quarry contains an estimated 1.2 million tons of indicated resources. An additional 2.2 billion tons of inferred resources of similar composition are present in carbonate rocks exposed west of the quarry area, including 1.7 billion tons inside the roadless area. The Sugarloaf Mountain prospect has an estimated 3.3 million tons of indicated and 30 million tons of inferred resources.

Magnesian marble resources in the study area are suitable for use as industrial aggregate and agricultural soil conditioners, but have too much magnesium, silica, and loss on ignition to be suitable for cement or pigment production.

[2]"Amorphous" graphite actually consists of microscopic crystals. The term flake refers to graphite made up of a number of parallel laminae, which may be separated solely by mechanical means from its host rock. Flake graphite is uniform in quality, free from foreign material, and greater than 14 mesh size (Taylor, 1980, p. 384; Office of Industrial Minerals, Business, and Defense Services Administration, 1970, p. 2).

[3]Fixed carbon is the carbon remaining after low-temperature heating. It includes graphite and forms of noncrystalline carbon, such as charcoal.

Most of these resources have been claimed at various times since the 1940's, but the only reported production was a few tons of construction aggregate mined at the Green Canyon quarry. Superior carbonate-rock deposits outside the roadless area are already developed. Because all the magnesian marble within the roadless area was used to calculate the marble resources of the area, there is no potential for additional marble resources within the roadless area, although additional resources are present outside the area.

Uranium

No uranium resources have been identified in pegmatite at the Thirsty King prospect or in any other pegmatite found within the Sugarloaf Roadless Area. Outside the roadless area at the Thumbum mine, supergene occurrences contain an estimated 320,000 tons of indicated and 620,000 tons of inferred resources averaging 0.01 weight percent U_3O_8. Because this grade is too low for economic extraction at present, the demonstrated and inferred resources in the vicinity of the study area are subeconomic. With the large tonnages potentially available, the supergene deposit could be mined by open-pit methods under substantially more favorable market conditions. At the B and B prospect, also outside the roadless area, all the known low-grade uranium ore has already been stockpiled. Based on our studies, we conclude that the part of the roadless area underlain by Precambrian gneiss, with sparse pegmatite dikes, has low to moderate potential for low-grade uranium resources in minor deposits.

Other commodities

Stone other than magnesian marble is abundant, but no claims or leases have been located on deposits within or near the study area; similar deposits are equally abundant and accessible outside the area. Sand and gravel within the study area are restricted to active alluvial deposits in narrow stream beds, small terraces above the Santa Ana River, and small, relatively inaccessible volumes of Miocene sandstone and conglomerate. Superior deposits, both developed and undeveloped, exist outside the study area.

Gold and silver occur at the Pashby-Strong prospect, but concentrations are so low that no resource or evidence for a resource potential is identified. Elsewhere in the Transverse Ranges, a strong correspondence exists between the presence of gold and silver and tungsten mineralization and a weaker correspondence exists between the presence of gold and silver and copper, molybdenum, bismuth, and lead (Evans, 1982; Obi and others, 1983; R. E. Powell and others, 1983, unpublished maps, U.S. Geological Survey, Menlo Park, Calif.). Compared to stream-sediment concentrations of these associated elements from nearby areas known to be mineralized, the isolated low concentrations detected for tungsten, silver, and molybdenum, the generally low values for lead, and the nondetection of bismuth provide no evidence for a potential for the presence of metallic mineral resources in the Sugarloaf Roadless Area. Where gold and silver deposits occur elsewhere in the Transverse Ranges (Evans, 1982; Matti and others, 1982; R. E. Powell and others, 1983, unpublished maps, U.S. Geological Survey, Menlo Park, Calif.), geologic and geochemical evidence for mineralization is much stronger and mining is more extensive than they are in the immediate vicinity of the study area.

Slight concentrations of tin and thorium may be related either to non-ore rock-forming minerals or to the products of a very weak mineralizing system. However, compared to stream-sediment concentrations from nearby areas known to be mineralized, the values detected in samples from the study area are low.

We found no evidence for energy mineral resources other than uranium.

No previously unknown mineral occurrence was located during this study.

The principal magnetic and gravity anomalies in the study area correspond with a lithologic unit of measured high magnetic susceptibility and high density relative to surrounding units, rather than to an undiscovered mineral deposit.

REFERENCES CITED

Biehler, Shawn, Tang, R. W., Ponce, D. A., and Oliver, H. W., 1983, Preliminary Bouguer gravity map of California, San Bernardino sheet: U.S. Geological Survey Open-File Report 83-96, scale 1:250,000.

Cameron, C. S., 1981, Geology of the Sugarloaf and Delamar Mountain areas, San Bernardino Mountains, California: Ph.D. thesis, Massachusetts Institute of Technology, Cambridge, 399 p.

———1982, Stratigraphy and significance of the Upper Precambrian Big Bear Group: in Cooper, J. D., compiler, Geology of selected areas in the San Bernardino Mountains, western Mojave Desert, and southern Great Basin, California, Guidebook and volume for Field Trip Number 9, 78th Annual Meeting of the Cordilleran Section, Geological Society of America, p. 5-20.

Campbell, H. W., 1983, Mineral investigation of Sugarloaf (Rare II) Area (No. 5186), San Bernardino County, California: U.S. Bureau of Mines Open-File Report MLA 9-83, 18 p. with map.

Dibblee, T. W., Jr., 1964, Geologic map of the San Gorgonio Mountain quadrangle, San Bernardino and Riverside Counties, California: U. S. Geological Survey Miscellaneous Geologic Investigations Map I-431, scale 1:62,500.

du Bray, E. A., Dellinger, D. A., Oliver, H. W., Diggles, M. F., Johnson, F. L., Thurber, H. K., Morris, R. W., Peters, T. J., Lindsey, D. S., 1982, Mineral resource potential map of the John Muir Wilderness, Fresno, Inyo, Madera, and Mono Counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1185-C, scale 1:125,000.

Evans, J. G., 1982, Geologic and geochemical evaluation of mineral resources of the Sheep Mountain Wilderness Study Area and the Cucamonga Wilderness and additions, Los Angeles and San Bernardino Counties, California: U.S. Geological Survey Bulletin 1506-C, p. 33-51.

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.

Guillou, R. B., 1953, Geology of the Johnston grade area, San Bernardino County, California: California Division of Mines, Special Report 31, 18 p.

Levinson, A. A., 1980, Introduction to exploration geochemistry, second edition: Applied Publishing Ltd., Wilmette, Illinois, 924 p.

Matti, J. C., Cox, B. F., Rodriguez, E. A., Obi, C. M. , Powell, R. E., Hinkle, M. E., and Griscom, Andrew, 1982, Mineral resource potential map of the Bighorn Wilderness Study Area (CDCA-217), San Bernardino County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1493-A, scale 1:48,000.

McJunkin, R. D., 1976, Geology of the central San Bernardino Mountains, San Bernardino County, California: California State University, Los Angeles, M.S. thesis, 102 p.

Miller, F. K., and Morton, D. M., 1980, Potassium-argon geochronology of the Eastern Transverse Ranges and southern Mojave Desert, southern California: U.S. Geological Survey Professional Paper 1152, 30 p.

Obi, C. M., Matti, J. C., and Cox, B. F., 1983, Stream-sediment geochemical survey of the Bighorn Mountains Wilderness Study Area (CDCA-217), San Bernardino County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1493-B, scale 1:48,000 [in press].

Office of Industrial Minerals, Business, and Defense Services Administration, 1970, Graphite, natural crystalline: U.S. Department of Commerce, National Stockpile Purchase Specification P-22a-R3, 4 p.

Oliver, H. W., 1982, Geophysical studies of the Minarets Wilderness and adjacent areas, Madera and Mono Counties, California; Chapter B in Mineral resources of the Minarets Wilderness and adjacent areas, Madera and Mono Counties, California: U.S. Geological Survey Bulletin 1516, p. 49-72.

Peddie, N. W., Jones, W. J., and Fabiano, E. B., 1976, Magnetic inclination in the United States, Epoch 1975.0: U.S. Geological Survey Miscellaneous Investigations Map I-912, scale 1:5,000,000.

Powell, R. E., Matti, J. C., Rodriguez, E. A., and Cox, B. F., 1983, Stream-sediment geochemical survey of the Sugarloaf Roadless Area, San Bernardino County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1606-B, scale 1:24,000 [in press].

Rohtert, W. R., 1979, Thumbum uranium project: Portland General Electric Company in-house report, available U.S. Bureau of Mines Western Field Operations Center Library, Spokane, Washington, 24 p.

——1981, Paragenesis of the Thumbum uranium deposit, San Bernardino Mountains, California: University of Colorado, Boulder, Ph.D. thesis, 149 p.

Sadler, P. M., 1982, Geologic map of the Moonridge quadrangle, California: California Division of Mines and Geology, San Francisco, scale 1:24,000.

Saltus, R. W., and Blakely, R. J., 1983, Hypermag: an interactive, two dimensional gravity and magnetic modeling program: U.S. Geological Survey Open-File Report 83-241, 28 p.

Silver, L. T., 1971, Problems of crystalline rocks of the Transverse Ranges (abs.): Geological Society of America, Abstracts with Programs, v. 3, no. 2, p. 193-194.

Strathouse, E. C., 1981, Geologic report, Agreement No. 5-1106: Regional Mapping Project Data Base Augmentation Program: California Division of Mines and Geology, San Francisco, 6 p.

——1982, The Santa Ana Sandstone (Miocene, in part) and evidence for Late-Cenozoic orogenesis in the San Bernardino Mountains: in Cooper, J. D., compiler, Geologic excursions in the Transverse Ranges, Volume and Guidebook for the 78th Annual Meeting of the Cordilleran Section, Geological Society of America, p. 97-102.

Streckeisen, A. L., 1973, Plutonic rocks: classification and nomenclature recommended by the IUGS Subcommission on the Systematics of Igneous Rocks: Geotimes, v. 18, n. 10, p. 26-30.

Tang, R. W., and Ponce, D. A., 1982, Principal facts, accuracies, sources, and base station descriptions for 4915 gravity stations on the San Bernardino 1^{o} x 2^{o} quadrangle, California: U.S. Geological Survey Report No. GD 82-004, 99 p., available from U.S. Department of Commerce, National Technical Information Service, Springfield, VA 22161, NTIS-PB-200312.

Taylor, H. A., Jr., 1980, Graphite, in Mineral Facts and Problems: U.S. Bureau of Mines Bulletin 650, p. 383-394.

Troxel, B. W., Stinson, M. C., and Chesterman, C. W., 1957, Uranium, in Jenkins, O. P., director, Mineral Commodities of California: California Division of Mines Bulletin 176, p. 669-687.

Turekian, K. K., 1977, Geochemical distribution of chemical elements in the earth's crust: Geochemistry, v. 1, p. 1-43.

U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, 5 p.

U.S. Geological Survey, 1982, Aeromagnetic map of the Bighorn area, California: U.S. Geological Survey Open-File Report 82-664, scale 1:62,500.

Vacquier, Victor, Steenland, N. C., Henderson, R. G., and Zietz, Isidore, 1951, Interpretation of aeromagnetic maps: Geological Society of America Memoir 47, 151 p.

Vaughan, F. E., 1922, Geology of San Bernardino Mountains, north of San Gorgonio Pass: University of California, Department of Geological Sciences Bulletin, v. 13, p. 319-411.

Warne, J. D., and Reeves, R. G., 1957a, Report of examination of field team, Rocky Point claim, San Bernardino County, California: Defense Minerals Administration Report 4602, 7 p.

——1957b, Report of examination of field team, Thumbum et al., claims San Bernardino County, California: Defense Minerals Administration Report 4563, 7 p.

Western Prospector, 1973, Big graphite discovery: July-August 1973, p. 6.

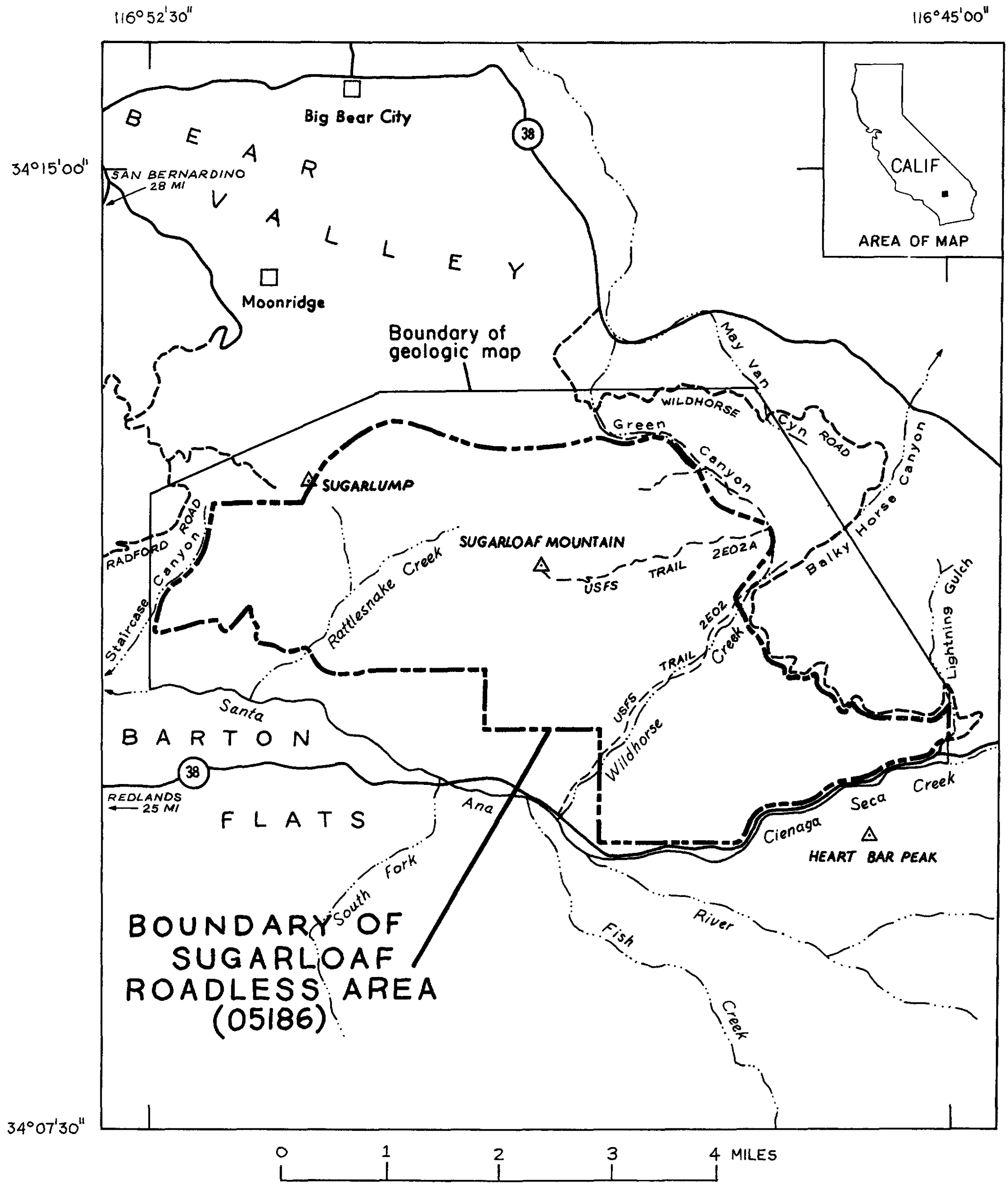
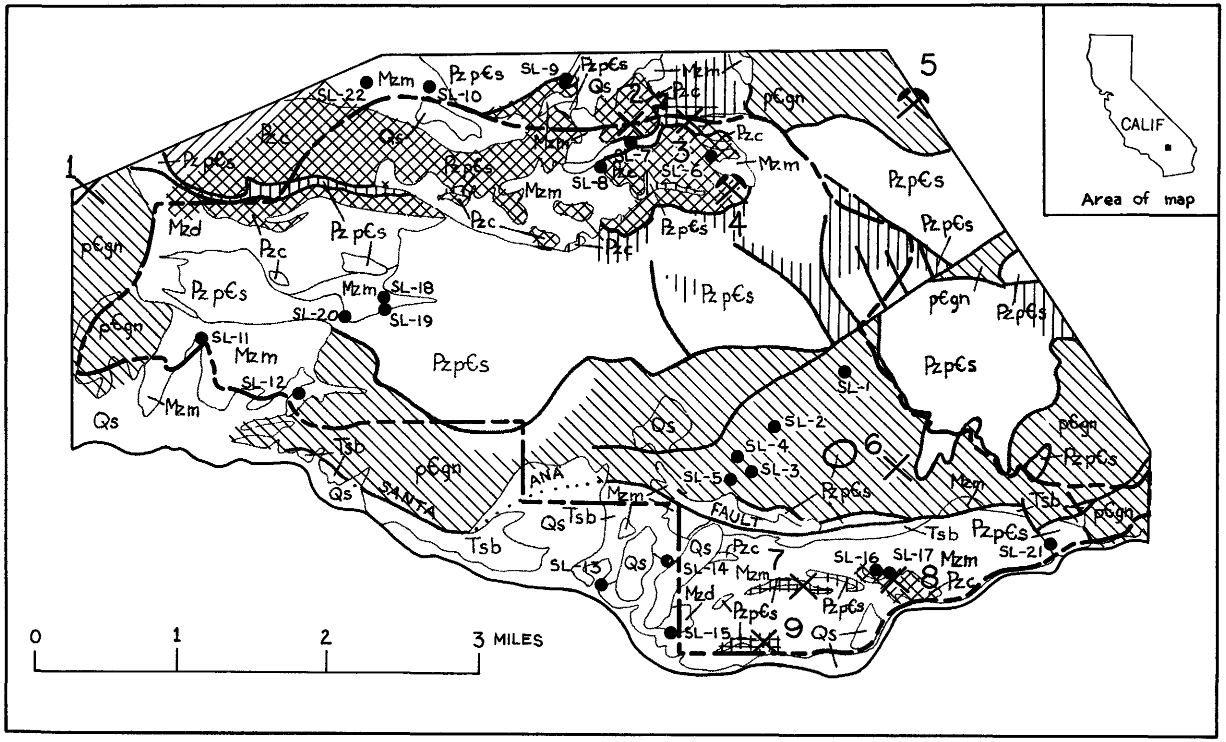


Figure 1.--Index map showing location of the Sugarloaf Roadless Area (05186), San Bernardino County, Calif.



GEOLOGIC UNITS

Qs	Surficial deposits (Quaternary)—Alluvium, colluvium, and talus
Tsb	Sandstone, conglomerate, and basalt (Tertiary)
Mzm	Monzodiorite and quartz diorite (Mesozoic)
Mzd	Diorite and gabbro (Mesozoic)
Pzc	Carbonate rocks (Paleozoic)
Pzp€s	Schist, phyllite, siltite, and quartzite (Precambrian and (or) Paleozoic)
p€gn	Gneiss (Precambrian)

MINE, QUARRY, AND PROSPECTS

1 B and B prospect
2 Pashby-Strong prospect
3 Princes Graphite prospect
4 Green Canyon quarry
5 Thumbum mine
6 Thirsty King prospect
7 St. Francis Graphite upper prospect
8 Sugarloaf Mountain prospect
9 St. Francis Graphite lower prospect

EXPLANATION

MINERAL RESOURCE AND RESOURCE POTENTIAL AREAS

- Demonstrated or inferred magnesian marble resources
- High potential for magnesian marble resources
- Demonstrated or inferred low-grade graphite resources
- Low potential for low-grade graphite resources in minor deposits
- Low to moderate potential for low-grade uranium resources in minor deposits

- 5 MINE OR QUARRY
- 6 PROSPECT
- SL-1 STREAM-SEDIMENT SAMPLE LOCALITY
- CONTACT
- FAULT--Dotted where concealed
- APPROXIMATE BOUNDARY OF ROADLESS AREA

Figure 2.--Areas having identified mineral resources and mineral resource potential and locations of mines and prospects, Sugarloaf Roadless Area. Geology simplified from accompanying mineral resource potential map.