MINERAL RESOURCE POTENTIAL OF THE BIGHORN MOUNTAINS WILDERNESS STUDY AREA (CDCA-217), SAN BERNARDINO COUNTY, CALIFORNIA

SUMMARY REPORT

By

Jonathan C. Matti, Brett F. Cox, Eduardo A. Rodriguez, Curtis M. Obi, Robert E. Powell, Margaret E. Hinkle, and Andrew Griscom
U.S. Geological Survey

and

Charles Sabine and Gary J. Cwick
U.S. Bureau of Mines

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 in certain areas to determine their mineral resource potential. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Bighorn Mountains Wilderness Study Area (CDCA-217), California Desert Conservation Area, San Bernardino County, California.

SUMMARY

Geological, geochemical, and geophysical evidence, together with a review of historical mining and prospecting activities, suggests that most of the Bighorn Mountains Wilderness Study Area has low potential for the discovery of all types of mineral and energy resources—including precious and base metals, building stone and aggregate, fossil fuels, radioactive-mineral resources, and geothermal resources. Low-grade mineralization has been documented in one small area near Rattlesnake Canyon, and this area has low to moderate potential for future small-scale exploration and development of precious and base metals. Thorium and uranium enrichment have been documented in two small areas in the eastern part of the wilderness study area; these two areas have low to moderate potential for future small-scale exploration and development of radioactive-mineral resources.

INTRODUCTION

The Bighorn Mountains Wilderness Study Area is located in southern California in the Bighorn Mountains and adjacent parts of the northeastern San Bernardino Mountains (fig. 1). The study area lies about 15 mi northwest of Yucca Valley, and encompasses an area of approximately 35 mi^2 (22,400 acres) that adjoins the San Bernardino National Forest. The study area mainly occupies low mountains and high plateaus of the California high desert, and is traversed by Rattlesnake Canyon creek, an ephemeral stream that flows northward into Johnson Valley in the Mojave Desert. Rugged, mountainous terrain occurs in the southwestern part of the study area in the vicinity of the 7,500-ft-high Granite Peaks. Access to the study area is gained by numerous unimproved dirt roads that lead southward and westward into the area from State Highway 247, and northward from New Dixie Mine Road and Viscera Spring Road.

Geologic setting

Rocks in the vicinity of the Bighorn Mountains Wilderness Study Area have been examined by two earlier workers. Dibblee (1964, 1967a, b, c) published reconnaissance geologic maps of the vicinity, and Sadler (1982b, c, d, e) mapped part of the study area during his regional studies of the structural geology of the eastern San Bernardino Mountains (Sadler, 1982a, f).

The Bighorn Mountains Wilderness Study Area is underlain mainly by crystalline bedrock. We group these rocks into a prebatholithic suite of metasedimentary schist and paragneiss, a deformed plutonic suite of early(?) Mesozoic intrusive rocks, and an undeformed plutonic suite of late Mesozoic intrusive rocks. Tertiary and Quaternary sedimentary deposits fringe the mountains.

Prebatholithic suite

A distinctive assemblage of prebatholithic metasedimentary rocks is exposed in the southwestern part of the study area in the vicinity of Granite Peaks. This assemblage consists mainly of biotite schist and schistose biotite-quartz paragneiss, but also includes minor phyllite, laminated metaquartzite, and marble. Lithologically similar pods of biotite schist and gneiss that crop out in the central and eastern parts of the study area most likely are extensions of these metasedimentary rocks, although we have not confirmed this correlation. We believe that the schist and paragneiss assemblage on Granite Peaks is Paleozoic in age. This age assignment is based on lithologic correlation of these metasedimentary rocks with similar metasedimentary rocks in Jacoby Canyon 5 mi west of the map area. Stewart and Poole (1975) correlated the Jacoby Canyon metasedimentary rocks with Great Basin upper Precambrian and lower Paleozoic miogeoclinal sedimentary units.

In the Rattlesnake Canyon area, we have grouped bodies of metasedimentary gneiss and schist together with associated biotite-rich granodiorite and augen gneiss that contain megacrysts of potassium feldspar. These megacryst-bearing rocks represent either deformed Mesozoic granitoid rocks that intruded the metasedimentary gneiss, or Precambrian orthogneiss on which the metasedimentary rocks were deposited or with which they were tectonically juxtaposed.

Deformed plutonic suite

The deformed plutonic suite comprises a heterogeneous assemblage of orthogneiss and foliated to compositionally layered plutonic rocks that includes leucocratic, mesocratic, and mafic lithologies. Although we understand the age and sequencing relations of some of these units, the relations of other units are not so clear.

Much of the deformed plutonic suite consists of leucocratic to mesocratic granitic gneiss that is well foliated, or that has compositionally layered fabrics in which the layering is streaky and diffuse to conspicuous. In the eastern part of the wilderness study area two discrete gneiss units are present. A younger porphyritic granodiorite to granodioritic augen gneiss that contains conspicuous megacrysts of potassium feldspar has intruded an older, leucocratic to mesocratic, compositionally layered granitic gneiss that generally lacks megacrysts. The older granitic gneiss extends westward throughout the study area, cropping out extensively near Black Mountain, in the Bighorn Mountains, in the Rattlesnake Canyon area, and on the northern flank of Granite Peaks. In the Granite Peaks area the granitic gneiss terrane is characterized by leucocratic biotite granodiorite and gneissic granodiorite that have been mylonitized. These rocks have a pervasive west-northwest-trending mylonitic foliation and a conspicuous northeast- to southwest-plunging lineation that consists of biotite and quartz concentrations that have been streaked out down the dip of the foliation. Here, the granitic gneiss terrane represents plutonic rocks that have invaded and partly assimilated the prebatholithic metasedimentary rocks, which are preserved as bodies and xenoliths of biotite gneiss and schist and metaquartzite within the gneissose granitoid rock. During or following their emplacement, the plutonic rocks were deformed and mylonitized.

Although intrusive or emplacement ages for plutonic protoliths within the granitic gneiss terrane generally are poorly constrained, in the Granite Peaks area the terrane most likely is Mesozoic in age, and may be early Mesozoic or even late Paleozoic. Here, the plutonic protolith for the mylonitic gneiss has intruded lower Paleozoic metasedimentary rocks, and in turn has been intruded by undeformed late Mesozoic plutons. Therefore, the protolith for the mylonitic gneiss was intruded either during the late Paleozoic or, more likely, the early Mesozoic. Farther east, in the Bighorn Mountains and near Black Mountain, the age of the protolith for the deformed plutonic suite is more uncertain. Some of the leucocratic and mesocratic orthogneiss in these areas may have been intruded during the Precambrian, as suggested by previous workers (Dibblee, 1964, 1967c; Sadler, 1982c, d, e). However, a Precambrian age for these rocks seems unlikely because they are very similar to Mesozoic gneiss of the Granite Peaks area. The mylonitic granitoid rocks of Granite Peaks pass transitionally into layered granitic gneiss of the Bighorn Mountains-Black Mountain district, and tracts of mylonitic rock similar to rocks in the vicinity of Granite Peaks occur locally throughout the terrane. Thus, we believe that the granitic gneiss unit throughout the study area represents a single petrologic-structural terrane of deformed plutonic rocks that was intruded during the late Paleozoic or early Mesozoic. Compositional variation throughout this terrane reflects the presence of several plutonic protoliths, and textural variation reflects changes in the style and intensity of deformation.

The deformed plutonic suite also includes a few large bodies and small scattered lenses of mafic plutonic rocks that occur as inclusions within the granitic gneiss. These mafic rocks consist of hornblende gabbro, hornblende diorite, hornblende quartz diorite, and amphibolite. In the canyon of Arrastre Creek near the west margin of the study area, these mafic plutonic rocks intrude schist and marble of the Paleozoic prebatholithic suite. The mafic rocks have fabrics ranging from undeformed to strongly deformed; the amphibolite bodies in particular are strongly deformed, as indicated by isoclinal folds and by alined hornblende crystals that define a conspicuous lineation. The amphibolite bodies and lenses represent either deformed phases of the texturally massive rocks, or older phases intruded by the undeformed rocks. Mafic rocks of the deformed plutonic suite probably also were intruded during the late Paleozoic or early Mesozoic, although somewhat earlier than the leucocratic to mesocratic rocks of the deformed plutonic suite.

Undeformed plutonic suite

The undeformed plutonic suite consists of texturally massive to slightly foliated late Mesozoic plutonic rocks. For the simplified geology of the accompanying mineral resource potential map, we have grouped several plutonic lithologies into a single unit of leucocratic biotite-bearing granitoid rock that consists mainly of granodiorite and lesser amounts of monzogranite, quartz monzonite, granite, and distinctive garnetiferous muscovite-biotite leucogranite and granodiorite. Older rocks in this suite include a large body of foliated, sphene-bearing biotite-hornblende quartz diorite that has engulfed elongate arcuate bodies of mafic hornblende-biotite quartz diorite. In the eastern part of the study area, the undeformed plutonic suite is cut by latite, aplite, and quartz porphyry dikes that parallel joint patterns in the late Mesozoic granitoid units. All units of the undeformed plutonic suite intrude the granitic gneiss units of the deformed plutonic suite.

Tertiary and Quaternary units

Tertiary rock units crop out sparsely within and marginal to the wilderness study area. In the eastern part of the mapped area, bodies of olivine basalt occur as intrusions and small flows. Localized outcrops of basalt also occur at the northern base of the Bighorn Mountains, where the volcanic rocks have been overridden by gneiss and granite along thrust faults. Localized outcrops of sandstone and cobbly sandstone occur marginal to the north boundary of the study area. Dibblee (1967c) and Saddler (1982d, f) assign these deposits to the Old Woman Sandstone. For the simplified geology of the accompanying mineral resource potential map, we have grouped alluvium deposited and transported by active streamflows together with older deposits of dissected Pleistocene alluvium. These deposits consist of unconsolidated to well-consolidated gravel and sand.

Metamorphism and deformation

Metasedimentary rocks of the prebatholithic suite display considerable range in metamorphic grade. Near Granite Peaks these rocks contain metamorphic biotite and muscovite; elsewhere, presumably correlative amphibolite-grade biotite-rich paragneiss locally contains sillimanite and (or) garnet. Cordierite occurs at one locality east of the mouth of Rattlesnake Canyon. Regional metamorphism of the metasedimentary rocks presumably is Mesozoic or latest Paleozoic in age, and may be related to emplacement of mafic and granitoid rocks of the deformed plutonic suite. The deformed plutonic rocks exhibit a variety of strain-induced features, including recrystallization, mylonitization, mineral streaking and grain alinement, strong foliation and grain lenticulation, and compositional layering. In the Rattlesnake Canyon area, the granitic gneiss has been folded together with the biotite paragneiss. Deformation of the plutonic rocks either accompanied or post-dated their emplacement during late Paleozoic or early Mesozoic time, but clearly occurred prior to late Mesozoic emplacement of the undeformed plutonic suite.

Faults and folds

Rocks within and marginal to the wilderness study area are broken by faults having strike-slip, normal, and thrust and reverse displacements. A major east-trending fault system along the northern mountain front consists of south-dipping thrust and reverse faults that during Pliocene and Pleistocene time carried crystalline bedrock northward over bedrock and Quaternary units of the desert floor (Sadler, 1982a, f). A major zone of south-dipping reverse faults occurs along the north base of Granite Peaks. This fault zone may be related to the Pipes Canyon fault in the Viscera Spring area; however, we have not demonstrated continuity of faulting between the two areas. Northwest-trending high-angle strike-slip and dip-slip faults in the vicinity of Rattlesnake Canyon and in the eastern part of the study area locally contain crushed and argillized fault gouge. The age of movement on these high-angle structures is not clear: some faults form scarps in Quaternary alluvium, but other faults may be Tertiary or Mesozoic in age, especially those that are intruded by aplite dikes or that locally are silicified.

We have recognized folds only in the prebatholithic suite and the deformed plutonic suite. In the Rattlesnake Canyon area, both biotite-rich paragneiss and mylonitic leucogranitic gneiss have been deformed into a well-preserved, moderately plunging, nearly isoclinal fold that is intruded by undeformed granitic rocks. A mile or so to the east, a large vestigial fold form is defined by entrained xenoliths of biotite paragneiss and mesocratic granitic gneiss that have been engulfed by structureless granitic rock of the undeformed plutonic suite.

GEOLOGY, GEOCHEMISTRY, AND GEOPHYSICS PERTAINING TO MINERAL RESOURCE ASSESSMENT

Geology

Although geologic environments that commonly are favorable for the occurrence of mineral deposits occur in the Bighorn Mountains Wilderness Study Area, except for a few small areas these environments have not produced economic deposits of precious or base metals and energy minerals. Favorable sites for mineralization might be expected in the following generalized geologic environments: (1) metasedimentary pendants and xenolith swarms; (2) the deformed plutonic suite, especially mafic intrusive rocks and compositionally layered granitic gneiss that contain quartz veins and quartz-feldspar segregations; (3) late Mesozoic intrusive rocks of the undeformed plutonic suite; and (4) zones of faulting and fracturing where rocks may have been altered by hydrothermal fluids.

Paleozoic metasedimentary rocks of the prebatholithic suite generally are not mineralized in the study area. In other parts of the eastern San Bernardino Mountains, in areas such as the Mineral Mountain, Holcomb Valley, and Bear Valley mining districts a few miles southwest and west of the study area, precious metals have been discovered in Paleozoic quartzite, metaquartzite, and marble that have been intruded by late Mesozoic plutons. Metasedimentary rocks that we infer to be Paleozoic in age crop out on the north flank of Granite Peaks, but these rocks consist mainly of unmineralized biotite-rich paragneiss and subordinate phyllite, and within the wilderness study area they are not intruded by late Mesozoic plutons. Elsewhere, isolated bodies of schistose biotite gneiss are scattered throughout the study area, but these bodies also do not show obvious signs of metallic mineralization and they generally are not associated with upper Mesozoic plutons of the undeformed plutonic suite.

Foliated granite, granitic gneiss, and mafic intrusive rocks of the deformed plutonic suite do not show evidence of significant mineralization. In these rocks, zones of alteration, pegmatites, and crosscutting quartz veins are uncommon, although quartz lenses and quartz-feldspar segregations parallel to foliation and layering occur in some compositionally layered gneiss. Scintillometer and mineralogy studies by the U.S. Bureau of Mines indicate that biotite-rich stringers associated with pegmatitic segregations locally yield high thorium values and modest uranium values, and commonly are enriched in monazite. However, pegmatitic segregations are common only where compositional layering is well developed, and therefore they are sparse in much of the gneiss terrane where the rocks mainly are foliated or are diffusely layered.

Granitoid rocks of the upper Mesozoic undeformed plutonic suite generally are not mineralized in the study area. These rocks do not display extensive alteration or quartz-vein networks except locally in the vicinity of contact zones, where the plutonic rocks have engulfed and assimilated bodies and pods of biotite-rich prebatholithic rock. We did not observe obvious signs of mineralization or alteration along these contacts, although scintillometer measurements and petrographic and analytical studies by the U.S. Bureau of Mines indicate that some contact zones locally are enriched in thorium-bearing monazite. Elevated tin values in geochemical analyses of stream sediments collected from drainages underlain by two-mica granodiorite and leucogranite suggest that these rocks locally may be enriched in disseminated tin; however, we did not observe evidence of mineralized rocks in these areas.

Except for argillization and silicification, we did not observe mineralized rock within fault zones.

Geochemistry

A reconnaissance geochemical survey of stream sediment in the Bighorn Mountains Wilderness Study Area was conducted for 32 major, minor, and trace elements to identify any spatial variations in stream-sediment chemistry that might reflect local concentrations of ore minerals. We sampled alluvial sediment at 316 localities throughout the wilderness study area and vicinity (J. C. Matti, B. F. Cox, C. M. Obi, and M. E. Hinkle, unpub. data, 1982). Two samples of stream alluvium were collected from each of the 316 sample sites: (1) a bulk-sediment sample and (2) a panned concentrate rich in heavy minerals. Bulk sediment was selected as a sample medium because the geochemistry of sediment can reflect the bulk chemistry of bedrock terranes in the drainage basin. Panned concentrates were selected as a sample medium because many economically important elements either occur as native metals that can be concentrated together with heavy minerals, or occur preferentially within the heavy minerals themselves. For these elements, analysis of the panned concentrates is a more sensitive method of detecting geochemical anomalies within a drainage basin than analyses of the bulk-sediment sample alone.

Stream-sediment geochemistry can be a useful tool in reconnaissance mineral-resource evaluation because anomalously high concentrations of a specific element or group of elements in an alluvial deposit can reflect mineralization upstream in the drainage basin. However, the chemical composition of alluvium is influenced by numerous factors in addition to the mineral content of the source rocks (Rose and others, 1979, p. 383-427), and local geochemical anomalies commonly are unrelated to economic mineralization. Therefore, a stream-sediment geochemical survey is strictly a reconnaissance technique that produces results which must be evaluated within the context of geologic and geophysical data, as well as by followup geochemical studies.

The patterns of chemical composition determined by the stream-sediment geochemical survey of the Bighorn Mountains Wilderness Study Area do not indicate economic mineralization within the study area. Most of the analyses fall within ranges that are reasonable for nonmineralized crystalline rocks and derivative stream sediment, although background values for thorium and the rare-earth elements are higher than those for typical crustal rocks. Few elemental values are anomalous with respect to the average geochemical background for the study area.

Nonmetallic elements

In the vicinity of the Bighorn Mountains Wilderness Study Area, panned concentrates at many localities contain high concentrations of thorium, the rare-earth elements lanthanum and yttrium, and the transition metals niobium and scandium. The following ranges in abundance were measured for these elements: thorium, many values ranging between 1,000 and 2,000 ppm; lanthanum, many values exceeding 2,000 ppm (the upper limit of detection by emission spectrography); yttrium, values as high as 2,000 ppm; niobium, some values as high as 200 ppm; and scandium, many values as high as 100 ppm. In the bulk sediment, the mean concentrations of these elements include: thorium, most values were below the limit of detection (100 ppm); lanthanum, about 200 ppm; yttrium, 100 to 200 ppm; niobium, most values are below the level of detection (20 ppm); and scandium, about 30 ppm. Anomalously high concentrations of thorium and the rare-earth elements have no systematic distribution pattern in the vicinity of the wilderness study area. High concentrations were measured in samples of alluvium derived from the late Mesozoic undeformed plutonic suite as well as from mesocratic granitic gneiss of the deformed plutonic suite and metasedimentary rocks of the prebatholithic suite. Elevated values of thorium and the rare-earth elements generally occur together in samples collected throughout the study area, and we believe that the detected concentrations reflect higher-than-normal background concentrations of these elements in the plutonic and gneissic rocks of the district.

Uranium values in stream sediment range from 0.2 to 6 ppm, with a mean concentration of 1.0 ppm; this value is less than that of 3.9 ppm reported for granitoid rocks by Wedepohl (1969-78). Most of the higher uranium concentrations (greater than 2.0 ppm) were detected in samples from the eastern part of the study area.

In the same general area where uranium values are elevated, many panned concentrates contain greater than 2,000 ppm zirconium, accompanied by lanthanum concentrations ranging from 300 to greater than 2,000 ppm (the upper limit of detection by emission spectrography). We can only speculate about the origin of this coextensive distribution pattern for the zirconium-uranium-lanthanum association. These three elements possibly reflect high concentrations of zircon that may occur in rocks of the undeformed plutonic suite. Higher-than-average amounts of zircon may occur in granodiorite and muscovite-biotite leucogranite that crop out extensively in the eastern part of the wilderness study area and in areas to the southeast; alternatively, high concentrations of zircon may occur in aplitic and quartz porphyry latite dikes that cut the late Mesozoic plutons in this area.

Metallic mineralization

In panned concentrates, the approximate average concentrations for metallic elements include: copper, 35 to 50 ppm, with a few values as high as 200 ppm; tin, 50 to 70 ppm, with a few values of 100 to 150 ppm and one value of 300 ppm; tungsten, about 100 to 200 ppm, with a very few samples ranging from 500 to 2,000 ppm; lead, around 200 to 300 ppm, with a few values ranging from 1,000 to 5,000 ppm and one value each of 10,000 and 20,000 ppm; molybdenum, most values below the limit of detection, with a few values ranging from 50 to 200 ppm; bismuth, 50 to 100 ppm, with values ranging from less than 20 to 200-300 ppm and three values ranging from 1,000 to 2,000 ppm. In almost all the bulk-sediment samples, concentrations of tin, tungsten, molybdenum, and bismuth are below the detection limits (10, 50, 5, and 10 ppm, respectively). The mean values for lead range from about 35 to 50 ppm with very little variation. The mean value for copper averages about 50 ppm, with a few values of 100 ppm. The similarity of the mean values for copper in both panned-concentrate and bulk-sediment samples suggests that 50 ppm copper represents a general background level for copper in the study area.

Anomalous metallic concentrations are scattered throughout the study area. Higher-than-average concentrations of lead, in some samples accompanied by higher-than-average concentrations of copper, occur in a few isolated localities both within and outside the wilderness study area. Some anomalous lead and copper concentrations occur in the vicinity of mineral prospects inspected by the U.S. Bureau of Mines in the Rattlesnake Canyon area; other anomalous values are scattered throughout the crystalline-bedrock terranes. Higher-than-average concentrations of tungsten, molybdenum, and bismuth also are scattered throughout the study area, and in some samples are associated with mineral prospects. Higher-than-normal concentrations of tin occur mostly in the eastern part of the wilderness study area and vicinity, where these elevated values may be related to muscovite-biotite leucogranite and granodiorite of the undeformed plutonic suite. The highest chromium concentrations range up to 700 ppm in the panned concentrates, and occur mostly in the western part of the study area where mesocratic to leucocratic granitic gneiss of the deformed plutonic suite has intruded mafic plutonic rocks.

The anomalous concentrations of metallic elements generally occur at isolated sample sites. Metallic elements that occur in anomalous concentrations do not have systematic distribution patterns: none of these anomalous values are clustered tightly together within a geographic area or areas that might be the sites of large- or small-scale metallic mineralization. Most of the high metallic concentrations probably reflect isolated mineralized point sources, such as quartz veins or quartz-feldspar segregations in the gneissic rocks. Tin may be an exception: higher-than-average tin concentrations in the eastern part of the study area may be explained by tin disseminated in muscovite-biotite leucogranite and granodiorite of the undeformed plutonic suite. The anomalous elemental concentrations in the geochemical data represent expectable geochemical variation within the plutonic and gneissic crystalline rocks, and do not appear to represent significant indicators of metallic mineralization.

Geophysical surveys

Aeromagnetic and gravity maps of the Bighorn Mountains Wilderness Study Area were prepared as a geophysical contribution to the mineral-resource evaluation. These data were analyzed by Andrew Griscom (unpub. data, 1981).

Aeromagnetic survey

Magnetic anomalies and patterns on magnetic maps are caused by variations in the amount of magnetic minerals (commonly magnetite) in the rock units. Because they are related closely to geologic features, the magnetic-intensity contours can indicate economic concentrations of iron-rich minerals as well as terranes where these minerals are deficient. An aerial magnetic survey of the wilderness study area was flown in 1981. The trend and distribution of major magnetic lows and magnetic highs are illustrated in simplified form in figure 2. The unpublished aeromagnetic-contour map indicates that most of the magnetic anomalies and irregularities in magnetic patterns occur over rocks of the prebatholithic suite and the deformed plutonic suite. The magnetic expression of the late Mesozoic undeformed plutonic suite generally is one of low-amplitude anomalies and relatively smooth magnetic field; an exception is the occurrence of a 120-gamma high over a series of small mafic quartz diorite bodies that occur at the head of Ruby Canyon east of the Bighorn Mountains.

Comparisons between the aeromagnetic contours and areas where we have identified alteration or precious- and base-metal prospects suggest that two general correlations exist between magnetic signature and rocks that have been prospected extensively or that show traces of metallic mineralization. (1) A group of prospects in the vicinity of Rattlesnake Canyon is associated with the largest magnetic high in the wilderness study area (area A, fig. 2). This high is unexplained geologically. East of the high, other magnetic highs also seem to be associated with precious- and base-metal occurrences (areas B, C, D, fig. 2). Despite these spatial associations, the magnetic data do not seem to provide direct evidence for the existence or distribution of additional mineralized zones in the study area. (2) A more widely distributed group of metallic prospects and altered zones occurring throughout the eastern half of the wilderness study area clearly is associated with both linear and circular magnetic lows (areas E, F, G, H, I, fig. 2). The linear lows, which strike approximately N. 60° W., are associated with a set of faults having a similar trend. Magnetite in the country rocks near some of these faults may have been destroyed by hydrothermal alteration and (or) sulfide-bearing solutions migrating through crushed and fractured rock. Essentially all major magnetic lows of this type within the eastern half of the study area are associated with mineral prospects; similar lows that might indicate additional unidentified prospects do not occur elsewhere within the study area.

Prospects where we have measured radioactivity greater than twice the normal background level also are generally associated with areas of low magnetism. However, the radioactive-mineral prospects do not appear to correlate as well with specific magnetic features as do the metallic-mineral prospects. Accordingly, the magnetic map does not provide any evidence for the identification of additional radioactive-mineral prospects.

Gravity survey

Anomalies and patterns on gravity maps are caused by variations in density between the rock units. The unpublished gravity map indicates that in the western two-thirds of the study area, an irregular high of 8- to 10-mGal amplitude is associated with rocks of the prebatholithic suite and the deformed plutonic suite. The axis of this high trends east-west, and generally occupies the area having abundant outcrops of mafic hornblende diorite and outcrops of schistose biotite paragneiss. These rock units probably have the highest densities of any in the map area, and so it is appropriate that they are associated with a gravity high. In general, the small apparent density contrast between granitic gneiss of the deformed plutonic suite and granitoid rocks of the undeformed plutonic suite may explain the relatively featureless gravity map. The gravity data provide no evidence for possible economic mineralization.

Aeroradioactivity survey

The U.S. Department of Energy (1980) conducted an airborne gamma-ray-spectrometer survey that included the region of the Bighorn Mountains Wilderness Study Area. The flight lines for this regional survey were widely spaced (about 4 mi), and most of the wilderness study area occurs between two flight lines. Results of the regional survey indicate that high but extremely variable amounts of thorium might be expected in the study area. This inference was confirmed by the U.S. Bureau of Mines who identified locally high thorium concentrations in prospects scattered throughout the wilderness study area.

MINING DISTRICTS AND MINERALIZATION

Methods and previous studies

The U.S. Bureau of Mines reviewed individual mines, prospects, and mineralized areas in the Bighorn Mountains Wilderness Study Area. Prior to field studies, we reviewed literature pertaining to geology, prospecting, and mining in the area. We also searched mining-claim records on file with the U.S. Bureau of Land Management and with San Bernardino County to locate areas of past and present mining claims. During spring 1981, we examined and sampled all known mines and prospects and mapped larger or more mineralized properties as warranted. We measured radioactivity with scintillometers and, where warranted, with a gamma-ray spectrometer. Samples from radioactive zones (zones where scintillometer measurements exceed twice local background levels) were analyzed for uranium and thorium content and for radioactive-mineral identity at the U.S. Bureau of Mines Research Center, Reno, Nevada. Nonradioactive samples were analyzed for precious and base metals at a contract laboratory. Panned stream-sediment samples were collected and concentrated on a Wilfly Table to check for possible placer deposits of gold, monazite, and other heavy minerals.

Before this study, no thorough, systematic inventory of mineral deposits had been made for the Bighorn Mountains and vicinity. Wright and others (1953), Walker and others (1956), Dibblee (1964, 1967b, c), and Oesterling and Spurck (1964) reported briefly on some occurrences in the area.

Mining and prospecting history

The Bighorn Mountains Wilderness Study Area and surrounding lands are pocked by more than 140 prospect pits, 11 shafts, and nine adits; these workings reflect a long but sporadic history of mining activity. However, no production is reported from the area. The locations of workings are shown on the accompanying mineral resource potential map; tables 1 and 2 on the same map summarize geologic, mineralogic, and geochemical data from these workings.

Prospecting in the Bighorn Mountains area probably began in the 1870's, when the Holcomb Valley and Bear Valley mining districts, a few miles west of the wilderness study area, were active. The Surplus mine, which probably is presently named the Black Rattler (loc. 6), was active in the 1890's. In the first half of the 20th century, mining activity generally remained at a low level except for a flurry of gold prospecting during the 1930's. Prospecting flourished during the 1950's with the discovery of radioactive minerals in the area. Of the 1,100 claims recorded with San Bernardino County between 1892 and 1972, approximately 920 were filed during the 1950's. Most of the prospects and roads in the area were developed during that time.

U.S. Bureau of Land Management records dated December 1980 list 266 current mining claims in the Bighorn Mountains area, consisting of 234 lode claims and 32 placer claims. No development or production was taking place during our field studies, although one claim owner was planning a drilling project for radioactive minerals on his claims in sec. 23, T. 3 N., R. 3 E.

Mineralized areas

Radioactive minerals

Radioactivity exceeds twice the local background level in 24 prospecting areas (table 1), and samples from prospects in these areas were analyzed for uranium and thorium. The thorium content of 66 samples ranges from 30 to 6,780 ppm, with an arithmetic mean of 300 ppm. Uranium (as U_3O_8) ranges from 1.2 to 150 ppm, with an arithmetic mean of 8.8 ppm. Monazite is the principal thorium-bearing mineral in the study area.

Monazite concentrations occur in three types of deposits: pegmatite veins and segregations, igneous contacts, and placers. The largest and richest concentrations occur in what we informally refer to as nodular pegmatite veins and (or) segregations associated with granitic gneiss of the deformed plutonic suite. This rock consists of ovoid to lenticular pegmatitic quartz-feldspar intergrowths separated by thin biotite-rich stringers. Monazite is concentrated in these biotite stringers as discrete crystals that can be liberated by crushing, sizing, and density separation. At the Martin prospects (loc. 37), we traced a thorium-bearing, discontinuous nodular pegmatite in the mesocratic granitic gneiss unit for 1,000 ft in outcrop and in float. Samples from these prospects average 260 ppm thorium and 2.4 ppm U_3O_8. Nodular pegmatite also occurs at an unnamed prospect (loc. 54) where one very radioactive sample contains 6,780 ppm thorium and 150 ppm U_3O_8, the richest sample collected from the project area.

Most radioactive prospects occur in small mafic pods of biotite paragneiss and metadiorite associated with intrusive bodies of quartz monzonite, granodiorite, or pegmatite. Typically, the monazite is concentrated in biotite-rich layers within the gneiss or in thin zones along intrusive contacts, for example, at the Black Dog prospect (loc. 31) and unnamed prospects at locality 21. Although locally rich, monazite concentrations in these contact-zone deposits typically are small and spotty.

Concentrations of monazite occur as small pockets in stream sediments in drainages of Bighorn Canyon and Ruby Canyon, and in some drainages in the Black Mountain area.

Precious and base metals

Forty-one prospect areas summarized in table 2 of the accompanying mineral resource potential map were sampled for precious and base metals. The metallic content is negligible in most of the 126 samples; however, significant values were obtained from prospects at the Black Rattler (loc. 6), the Big Bucks (loc. 9), and the Plata (loc. 32).

The Black Rattler and Big Bucks claims both are developed in granitoid rock of the undeformed plutonic suite. Biotite-rich paragneiss of the prebatholithic suite and mesocratic granitic gneiss of the deformed plutonic suite occur nearby, and all the rocks have been broken by high-angle faults. Samples of pyritic quartz veins from surface workings and dumps at the Black Rattler contain significant amounts of gold, silver, lead, and copper. Underground workings, said by the owner to be extensive, were inaccessible. Samples from the Big Bucks yielded as much as 19.1 ppm gold and 1.15 percent copper, but limited exposure and inaccessible workings did not permit resource evaluation. Pyritic quartz lenses at the Plata contain as much as 11.2 ppm silver. Distribution of the silver is spotty, however, and the lenses appear to be small and not very widespread.

Panned stream-sediment concentrates from throughout the study area yielded only traces of gold, although some fingernail-size nuggets allegedly have been found in placers by prospectors in Rattlesnake Canyon.

Wright and others (1953, p. 113) mentioned a tungsten mine called the Blue Vase located east of Rattlesnake Canyon in sec. 2, T. 2 N., R. 3 E. We did not find any workings in this area that resembled the description of the Blue Vase, and no samples here showed anomalous tungsten values. However, we did find small amounts of scheelite in panned stream-sediment concentrates from Ruby Canyon and the Bighorn Canyon area.

Industrial resources

Low-grade talc, mixed with clay, silica, and feldspars, occurs in an altered contact zone between granitic rocks and a mafic pendant at the Kermodi claims (loc. 63). A near-horizontal zoned pegmatite (loc. 28) is similar in lithology and structure to the pegmatite at the Pomona tile quarry, a former producer of quartz and feldspar located northeast of the project area (Dibblee, 1967c). Oesterling and Spurck (1964, p. 179) mention occurrences of biotite, phlogopite, and vermiculite in the E1/2 sec. 13, T. 2 N., R. 3 E., that in their view "warrant further investigation". Although sand and gravel deposits occur sparsely within the study area, the development of these resources for construction stone is unlikely because the deposits are limited and because similar deposits outside the study area are more extensive and closer to present markets.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Geological, geochemical, and geophysical investigations, together with a review of prospecting and mining activities, suggest that most of the Bighorn Mountains Wilderness Study Area has low potential for economic development of all types of mineral resources and energy resources. This mineral-resource assessment is based on the following considerations. (1) Geologic mapping indicates that although geologic environments potentially favorable for mineralization occur within the study area, except for a few small areas these environments have not produced large deposits of precious and base metals and energy minerals. (2) Generally low concentrations of metallic and radioactive elements, determined by chemical analyses from 316 stream-sediment and panned-concentrate samples, indicate that elemental abundances generally fall within background ranges expected for nonmineralized rocks, although the background values for thorium, certain rare-earth elements, and zirconium appear to be higher than normal for crustal rocks. (3) Aeromagnetic patterns and gravity data do not point to the existence of economic concentrations of magnetic minerals. (4) Although prospecting activities have occurred sporadically over a long period, no production has been reported and no large deposits of metallic or radioactive minerals have been discovered. Therefore, we believe that most of the Bighorn Mountains Wilderness Study Area has low potential for the discovery of metallic and radioactive minerals, construction materials, fossil fuels, and geothermal resources.

Two small areas within the wilderness study area have low to moderate potential for future small-scale exploration and development of radioactive-mineral resources and one small area has low to moderate potential for future small-scale exploration and development of precious- and base-metal resources (fig. 3).

Radioactive-mineral resources

Although thorium-bearing monazite is abundant and widespread in the Bighorn Mountains Wilderness Study Area, individual occurrences generally are too small and spotty to be minable. Deposits at the Martin prospects (loc. 37) and the prospects at locality 54 might be large enough to support small-scale mining operations. Monazite concentrates could be produced easily and cheaply by simple crushing, sizing, and density separation; these concentrates then could be sold and refined for their thorium and rare-earth-element content.

Under existing market conditions and given the existing and future availability of easily developed monazite deposits elsewhere, development of the thorium-bearing monazite deposits at the Martin prospects and at locality 54 is unlikely. These deposits would have greater potential for development with the advent of a large open market for monazite, but such a market is not likely in the foreseeable future. In northeastern Florida, monazite presently can be recovered economically as a byproduct from Pleistocene beach sand that is mined for its titanium content. This source is expected to meet anticipated demand in the near future (Kirk, 1980). The United States has more than ample monazite reserves in vein deposits, carbonatites, and placers in Idaho, Colorado, California, and North and South Carolina to meet any unanticipated demand that might arise from construction of thorium-fueled nuclear reactors and from other new technologies (Staatz and others, 1979, 1980). Because of these considerations and because the monazite-bearing deposits at the individual prospects have limited extent, the potential for future development of the two largest radioactive-mineral prospects in the Bighorn Mountains Wilderness Study Area is low to moderate.

Precious and base metals

Sample results suggest that the vicinity of the Black Rattler and Big Bucks mines (locs. 6-9) has low to moderate potential for future small-scale exploration and development of precious- and base-metal mineralization. However, inaccessibility of underground workings precluded thorough examination, sampling, and estimation of resources. Silver values from the Plata claims (loc. 32) are significant, but the quartz lenses are too small to have economic potential.

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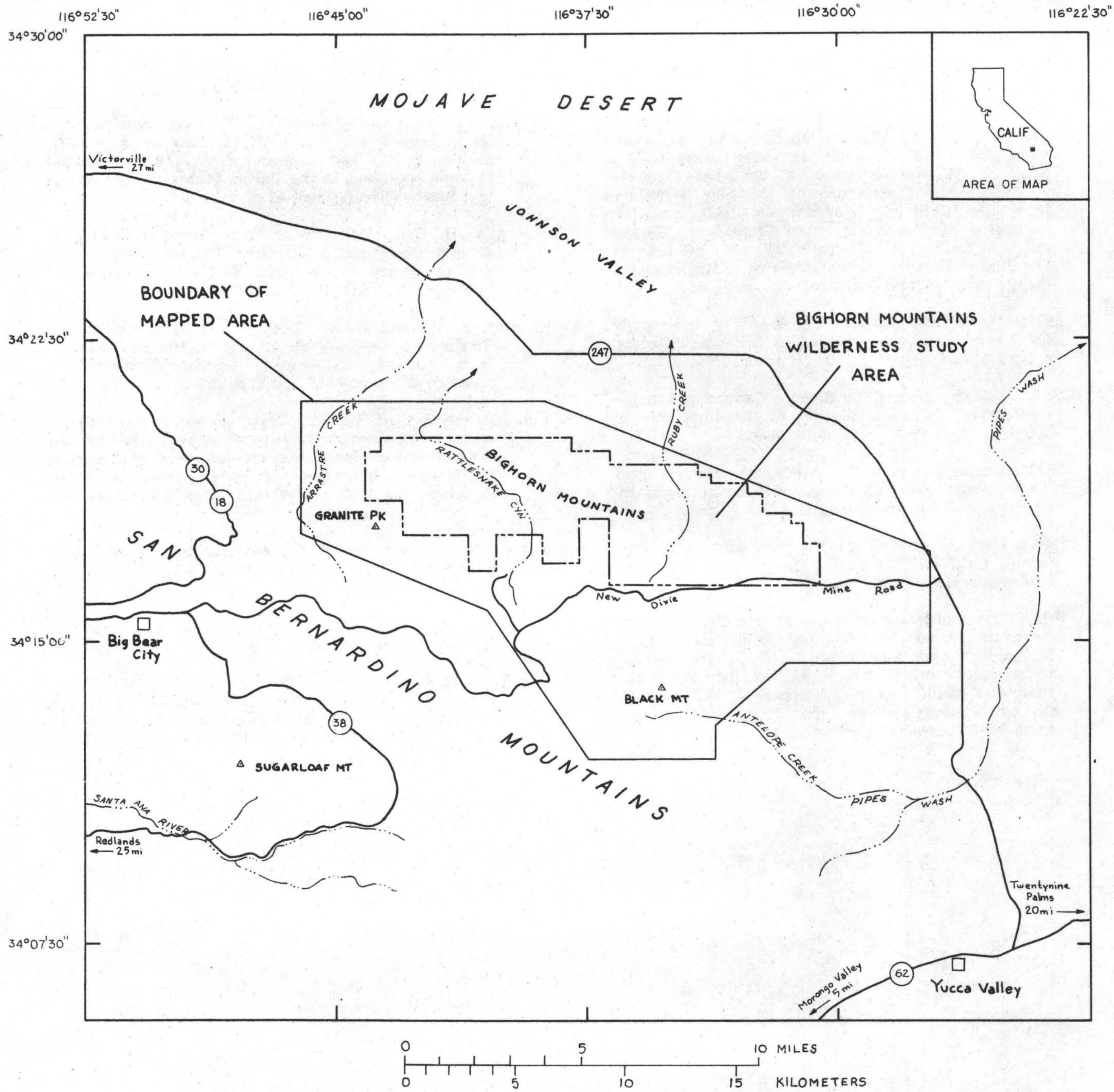
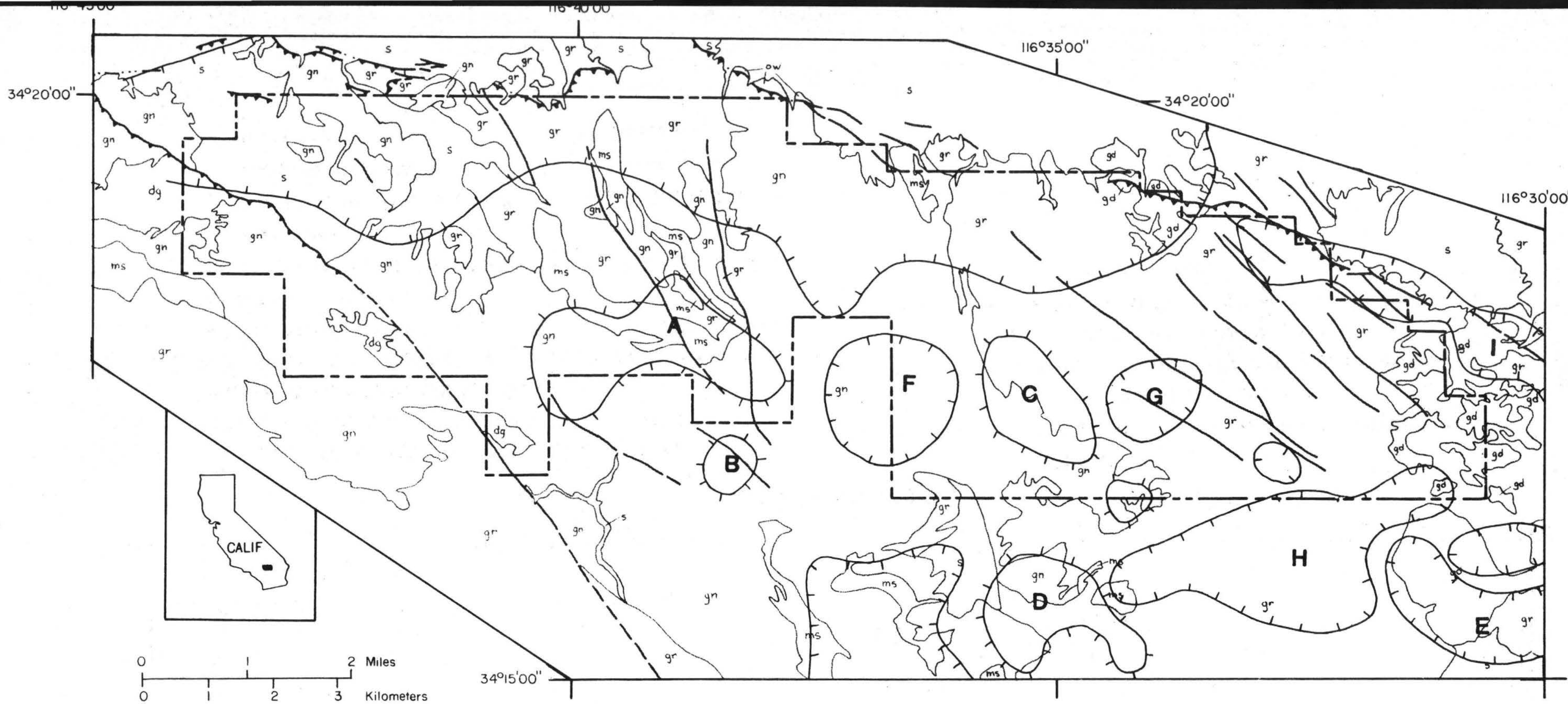


Figure 1.-- Index map showing location of the Bighorn Mountains Wilderness Study Area (CDCA-217), San Bernardino County, Calif.



EXPLANATION

BOUNDARY OF MAGNETIC HIGH OR LOW-- Hachures point in direction of lower magnetic-field intensity. Letters A-I refer to discussion in text

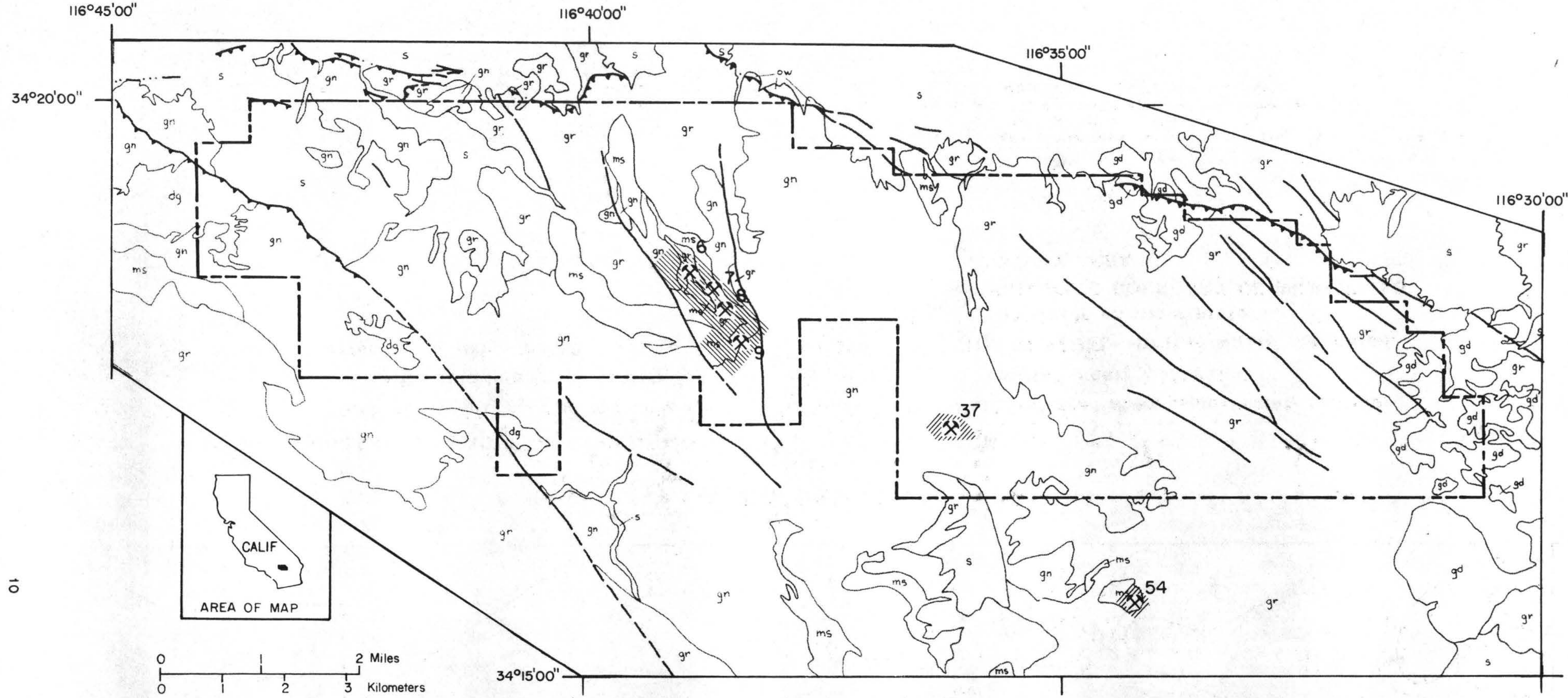
CONTACT

FAULT—Dashed where approximately located; dotted where concealed

THRUST FAULT--Dotted where concealed. Sawteeth on upper plate

APPROXIMATE BOUNDARY OF WILDERNESS STUDY AREA

Figure 2.--Simplified distribution of magnetic highs and lows in vicinity of Bighorn Mountains Wilderness Study Area (Andrew Griscom, unpub. data, 1981). Geology simplified from accompanying mineral resource potential map. s, surficial sedimentary deposits and older gravel deposits; ow, Old Woman Sandstone; gr, granitoid rocks of undeformed plutonic suite; gn, granitic gneiss of deformed plutonic suite; dg, dioritic and gabbroic rocks of deformed plutonic suite; ms, metasedimentary rocks of prebatholithic suite.



EXPLANATION

AREA OF LOW TO MODERATE POTENTIAL FOR FUTURE EXPLORATION AND DEVELOPMENT OF PRECIOUS- AND BASE-METAL RESOURCES

AREA OF LOW TO MODERATE POTENTIAL FOR FUTURE EXPLORATION AND DEVELOPMENT OF RADIOACTIVE MINERAL RESOURCES

⚒ PROSPECT OR MINERALIZED AREA--See tables 1 and 2 on map sheet

6 Black Rattler Nos. 1 and 2

7 Black Rattler No. 3

8 Unnamed

9 Big Bucks Nos. 1-3

37 Martin prospects

54 Unnamed

CONTACT

FAULT--Dashed where approximately located; dotted where concealed

THRUST FAULT--Dotted where concealed. Sawteeth on upper plate

APPROXIMATE BOUNDARY OF WILDERNESS STUDY AREA

Figure 3.--Bighorn Mountains Wilderness Study Area, showing zones with mineral resource potential and mines and prospects that occur within these zones. Geology simplified from accompanying mineral resource potential map. s, surficial sedimentary deposits and older gravel deposits; ow, Old Woman Sandstone; gr, granitoid rocks of undeformed plutonic suite; gn, granitic gneiss of deformed plutonic suite; dg, dioritic and gabbroic rocks of deformed plutonic suite; ms, metasedimentary rocks of prebatholithic suite.