MINERAL RESOURCE POTENTIAL OF THE RAYWOOD FLAT ROADLESS AREAS, SAN BERNARDINO AND RIVERSIDE COUNTIES, CALIFORNIA

SUMMARY REPORT

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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 submitted to the President and the Congress. This report discusses the results of a mineral survey of the Raywood Flat Roadless Areas (A5-187, B5-187), San Bernardino National Forest, San Bernardino and Riverside Counties, California. During the Second Roadless Area Review and Evaluation (RARE II) by the U. S. Forest Service in January 1979, area A5-187 was classified as a recommended wilderness; area B5-187 was classified as a further planning area.

SUMMARY

Geologic, geochemical, and geophysical studies within the Raywood Flat Roadless Areas, together with an investigation of mines and prospects within the further planning area, resulted in (1) identification of nonmetallic mineral resources[1] at a marble mine in the further planning area and (2) recognition of a small area in the recommended wilderness that has moderate potential for base-metal resources. Except for these two areas of identified and suspected resources, we did not observe indications of resource potential elsewhere in the Raywood Flat Roadless Areas.

The area having nonmetallic mineral resources is in the vicinity of the Mill Creek mine near the northeastern boundary of the further planning area (B5-187); there, we identified marginal reserves of marble suitable for the production of lime and construction stone. The reserves are marginal because of their remote location and poor accessibility. Geologic mapping did not reveal any additional marble occurrences within the study area.

The area having moderate potential for base-metal resources forms a small zone in the eastern part of the recommended wilderness (A5-187). Within this zone, evidence provided by stream-sediment geochemistry suggests that crystalline bedrocks in several drainages contain concentrations of metallic elements. Because the terrain is inaccessible and covered with dense brush, most of the bedrock in the specific drainages containing the geochemical anomalies could not be examined. Thus, although we infer that mineral occurrences exist in the drainage basins, we have little data on which to base an estimate of their extent and quality. Locally, the crystalline rocks probably contain hydrothermal veins or disseminated occurrences where lead, copper, molybdenum, tin, cobalt, bismuth, and arsenic have been concentrated. However, the geochemical anomalies for these metals are small, and the stream drainages also are relatively small. Therefore, the inferred occurrences of metallic minerals probably are small scale, scattered, and low grade. There is only low probability that the inferred mineral occurrences are large scale.

INTRODUCTION

The Raywood Flat Roadless Areas consist of a further planning area and a recommended wilderness area that are located in the southeastern San Bernardino Mountains, about 35 mi east of San Bernardino and about 10 mi north of Banning, Calif. (fig. 1). The further planning area (B5-187) constitutes about 29 mi^2 (18,615 acres); the recommended wilderness area (A5-187) constitutes about 35 mi^2 (22,320 acres). The roadless areas are situated adjacent to the existing San Gorgonio Wilderness, and consist of rugged mountainous terrain that includes Allen Peak (7,747 ft), Little San Gorgonio Peak (9140 ft), Galena Peak (9,330 ft), and Kitching Peak (6,598 ft). The study area is drained by major streams that include Mill Creek, several tributaries of Oak Glen Creek, San Gorgonio River, and the North and South Forks of Whitewater River. Access to the roadless areas is gained from several entry points. In Mill Creek Canyon, a paved

[1]The definition of resource follows established useage of the U.S. Bureau of Mines and U.S. Geological Survey (1980): "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". Defined in this broad fashion, a resource can contain extractable material (reserves) that can be developed now, and (or) additional material (marginal reserves, subeconomic resources) that feasibly may be developed in the future under more favorable market conditions and (or) with more advanced technological capability.

road that branches from State Highway 38 affords access to much of the further planning area; southern parts of this area can be entered by dirt roads that lead from Oak Glen Road, a paved road that follows Oak Glen Creek. Access to the recommended wilderness is by dirt roads leading up Millard Canyon and its major tributaries, and by permit on a private dirt road that leads up San Gorgonio River and terminates at Raywood Flat.

Uses and limitations

This report summarizes the results of geologic, geochemical, and geophysical surveys conducted in the Raywood Flat Roadless Areas by the U.S. Geological Survey and an investigation of mines, prospects, and mineralized areas conducted by the U.S. Bureau of Mines. The purpose of this study is to provide a mineral resource basis for land-use decisions regarding the study area and to target areas more suitable than other areas for additional mineral resource investigations. To achieve these goals, this study is designed to distinguish areas of lesser or greater resource potential based on differences in the type, scale, and degree of mineral concentration.

The techniques used in this investigation permit two types of reconnaissance evaluation: (1) where appropriate, we can estimate measured, indicated, or inferred resources for mines and prospects identified within the study area (mineral resource terminology follows the useage of U.S. Bureau of Mines and U.S. Geological Survey, 1980); (2) for geologic terranes that have no identified resources, we can judge whether high, moderate, or low potential exists for metallic, nonmetallic, or energy resources. The reconnaissance nature of this investigation limits our ability to make definitive statements about the geologic setting or resource content of either known or suspected mineral occurrences. We can identify areas that have potential for additional resource studies, and we can describe generalized geologic environments for particular minerals that are known or suspected to exist. In addition, for geologic terranes that have no identified resources we can provide limited judgments about the most likely scale of occurrence for undiscovered minerals, based on what we know about the geologic setting and geochemical or geophysical signatures and based especially on analogy with known occurrences in similar geologic settings elsewhere in the region. However, for mineral occurrences newly identified by us or indicated indirectly by geochemical or geophysical data, we can not document the quality and quantity of resources contained in such occurrences. Followup studies in the Raywood Flat Roadless Areas—involving additional geologic mapping, more detailed geochemical surveys of bedrock and stream-sediments, and drilling—would be necessary to document the geologic setting, extent, and grade of metallic, nonmetallic, or energy resources that may be present. Any resource potential we have assigned could be upgraded or downgraded based on new information or based on future changes in resource requirements.

GEOLOGIC SETTING

The San Bernardino Mountains consist of a high elongate block that has been uplifted to its present elevation during the last few million years (Sadler, 1982). Crystalline bedrock within this block records a complex sequence of geologic events. Early events that occurred in Mesozoic time include granitic plutonism, metamorphism of pre-plutonic sedimentary and igneous rocks, and folding, faulting, and penetrative shearing of both the plutonic and pre-plutonic units. These early events provided a geologic setting within which mineralization processes could have produced mineral deposits. The most recent geologic events have occurred during Tertiary and Quaternary time, when rocks that may have been mineralized during earlier events were redistributed within the mountain range and within the region by movements along faults. These events include (1) lateral movements on strike-slip faults of the San Andreas system that occur along the south margin of the range and (2) vertical and lateral movements on major thrust faults that flank the north margin of the range. Mineralization most likely did not occur during these latest geologic events.

Rocks within the Raywood Flat Roadless Areas record many elements of this geologic history. The study area is underlain mainly by crystalline bedrock that consists of granitoid plutonic rocks, gneissic plutonic rocks, and uncommon bodies of metasedimentary rock (fig. 2). Valley and upland areas locally contain Quaternary deposits of gravel and sand (Raywood Flat itself is an intermontane upland valley that contains dissected deposits of older gravel). Large and small landslide deposits occur on some hillslopes; these slope-failure deposits appear to be most common and most extensive in areas where active vertical uplift may be occurring, or where seismic ground shaking due to earthquake activity on nearby faults may provide a triggering mechanism. Three strands of the San Andreas fault system occur in the vicinity of the Raywood Flat Roadless Areas—the Mission Creek fault, the Mill Creek fault, and the south branch of the San Andreas fault. The south branch presently is the active strand of the San Andreas system. Although the Mill Creek and Mission Creek faults both appear to be strands that have been abandoned by the San Andreas system, many tens of miles of right-lateral displacement on these two faults have carried rocks northwestward into the Raywood Flat area from their original location in the Salton trough area.

Crystalline rocks

Crystalline rocks in the Raywood Flat Roadless Areas are divided into three suites by the two strands of the San Andreas fault system that traverse the study area (fig. 2): (1) rocks north of the Mill Creek fault; (2) rocks between the Mission Creek and Mill Creek faults; and (3) rocks south of the Mission Creek fault. The two crystalline suites separated by the Mill Creek fault resemble each other in a general way, whereas the crystalline suite south of the Mission Creek fault has several unique features not found in the other two suites. Similarities and differences among the three suites provide evidence for approximate and relative amounts of right-lateral displacement along the Mission Creek and Mill Creek strands of the San Andreas fault system.

Rocks north of the Mill Creek fault

Rocks north of the Mill Creek fault (fig. 2) have been described by Morton and others (1980) and by Cox and others (1983a) during their geologic investigations of the San Gorgonio Wilderness. The crystalline rocks consist of two distinct suites of gneissic rock that have been intruded by several varieties of granitoid rock. An older gneiss terrane consists of biotite-rich, compositionally layered Precambrian gneiss. A younger gneiss terrane includes a heterogeneous assemblage of foliated to gneissic granitoid rocks whose plutonic protoliths probably are mainly Mesozoic in age. These two gneiss terranes have been intruded by lithologically distinct varieties of Mesozoic granitoid rock that form plutons of moderate size. The plutonic rocks include leucocratic muscovite-biotite monzogranite (termed quartz monzonite by Morton and others, 1980), biotite granodiorite, hornblende-biotite granodiorite, and porphyritic hornblende quartz monzodiorite containing distinctive phenocrysts of potassium feldspar (rock nomenclature follows Streckeisen, 1973). The elongate arcuate extension of the Raywood Flat further planning area (B5-187) that is situated north of the Mill Creek fault is underlain mainly by the phenocryst-bearing quartz monzodiorite and by the biotite-rich gneiss unit. At its east end, this area is underlain by monzogranite and by gneissic plutonic rocks of the heterogeneous crystalline complex.

Rocks between the Mill Creek and Mission Creek faults

Crystalline rocks between the Mill Creek and Mission Creek faults (fig. 2) generally are similar to foliated and gneissic rocks north of the Mill Creek fault. Near the western end of the further planning area, this assemblage includes foliated biotite granodiorite that forms a discrete pluton of moderate size. However, in most areas the crystalline rocks are represented by biotite-bearing granitoid rocks that exhibit diffuse to conspicuous gneissic layering and that have compositions ranging from monzogranite to tonalite. Locally, pods of biotite-sillimanite-garnet schist, metaquartzite, and marble occur as inclusions within the foliated and gneissic plutonic rocks. As with the terrane of heterogeneous gneissic granitoid rocks north of the Mill Creek fault, this terrane between the Mill Creek and Mission Creek faults probably formed during Mesozoic time as a result of intense thermal and tectonic activity. These events involved partial melting of pre-existing continental crust, along with plutonism, migmatite formation, and deformation by pervasive ductile shearing. These processes probably occurred at intermediate or deep levels in the Earth's crust, and produced fabrics and structures that impart a metamorphic rather than plutonic appearance to the rocks.

Rocks south of the Mission Creek fault

South of the Mission Creek fault, the rocks consist of two distinct terranes separated by a steeply dipping thrust fault that is part of the region-wide Vincent-Orocopia thrust system (Ehlig, 1981, p. 266-277). Rocks in the lower plate of this thrust crop out in a restricted area in the headwaters of San Gorgonio River. There, the rocks consist mainly of albite-actinolite-chlorite-epidote greenstone that has been metamorphosed to greenschist facies. Subordinate lithologies include metachert, metasiltstone, and minor carbonate rock. These rocks are similar to the Pelona Schist of the San Gabriel Mountains 45 mi west of the study area.

Rocks in the upper plate of the Vincent-Orocopia thrust consist of a lithologically monotonous assemblage that includes foliated granitoid rocks, gneissic granitoid rocks, compositionally layered granitic gneiss, and pegmatite. Abundant epidote characterizes many of these rocks. The granitoid rocks and their gneissic equivalents have a range of compositions that includes leucocratic biotite granodiorite, mesocratic hornblende-biotite quartz diorite and tonalite, granodioritic orthogneiss, and distinctive hornblende- and potassium-feldspar-bearing porphyritic granodiorite that is lithologically similar to the Triassic Mount Lowe Granodiorite of the San Gabriel Mountains (Miller, 1926, introduced the name Mount Lowe Granodiorite; Ehlig, 1981, p. 262-263, discussed the petrology and regional correlation of the unit). Farley (1979) mapped the distribution of the Mount Lowe lithologies in the Raywood Flat area and discussed their affinity with similar rocks in the San Gabriel Mountains. Most of the plutonic rocks and most of the plutonic protoliths for the layered gneisses probably are Mesozoic in age, although bodies of Precambrian orthogneiss may be present. This crystalline terrane has been affected by one or more regional deformations that have crushed and sheared the rocks and have produced pervasive planar fabrics that include textural foliation, cataclastic and mylonitic foliation, and gneissic compositional layering. Mylonitic fabrics are especially well developed structurally low in the terrane, near the Vincent-Orocopia thrust in the headwaters of San Gorgonio River. Following the latest episode of deformation, the crystalline rocks were intruded by dikes of hypabyssal dacite porphyry and porphyritic basalt.

Faults

The two most conspicuous faults in the Raywood Flat Roadless Areas are the Mill Creek and Mission Creek faults. The Mill Creek fault is exposed best in the headwaters of Mill Creek, where the fault consists of a south-dipping zone of crushed and sheared rock that is about 700 ft wide. The shear planes do not disturb Quaternary older-gravel deposits that overlie the fault zone.

The Mission Creek fault is a complicated zone that traverses the South Fork of Whitewater River and splays into southern and northern strands in the vicinity of Raywood Flat. Both of these strands pass westward into the headwaters of San Gorgonio River, where the northern strand is truncated by the southern strand. The southern strand then curves southwestward and eventually is truncated by the south branch of the San Andreas fault. West of Raywood Flat, the two strands of the Mission Creek fault bound a small window of Pelona Schist that is overthrust by sheared and cataclasized upper-plate rock of the Vincent-Orocopia thrust. Here, both the upper-plate and lower-plate rocks differ significantly from their counterparts south of the southern strand, a relationship which suggests that the two strands of the Mission Creek fault have had distinct and separate geologic histories. We believe that the northern strand is an older strand that was active early in the history of the Mission Creek fault zone. Following an initial period of displacements on the northern strand, the southern strand became the main locus of lateral displacements; the southern strand probably has had greater displacements as evidenced by its wider shear zone. Neither fault appears to have been active since the deposition of Quaternary older-gravel deposits. The older gravels in the vicinity of Raywood Flat are disturbed by a fault that breaks the deposits to the east (Ehlig, 1977) and forms a topographic scarp in the deposits to the west, but we do not attribute this fault to Quaternary right-lateral activity within the Mission Creek fault zone. Instead, we believe this Quaternary deformation has been produced by a fault whose trace coincides with the Mission Creek fault system in the vicinity of Raywood Flat, but departs from it in the headwaters of San Gorgonio River.

The Mill Creek and Mission Creek fault zones both are right-lateral faults that once were major strands of the San Andreas fault system, but were abandoned by that system during late Quaternary time. Right-lateral displacements along both zones have resulted in lithologic differences across the faults. However, Holocene or late Pleistocene activity appears to have been minimal as evidenced by the fact that the faults have not broken Quaternary gravel deposits that depositionally overlie the zones. Lithologic contrasts across the Mission Creek fault system are greater than contrasts across the Mill Creek fault system, a relationship which suggests that right-lateral displacement on the Mission Creek fault zone has been greater than that on the Mill Creek fault zone (see Ehlig, 1977; Farley, 1979).

GEOLOGY, GEOCHEMISTRY, AND GEOPHYSICS PERTAINING TO MINERAL RESOURCE ASSESSMENT

Geology

Metallic mineralization

Although geologic environments that commonly are favorable for the development of mineral deposits occur in the Raywood Flat Roadless Areas, we did not observe evidence for significant occurrences of precious and base metals, nonmetallic minerals, or energy minerals. Favorable sites for mineralization in the study area might be expected in the following generalized geologic settings: (1) metasedimentary rocks that could contain contact-zone metasomatic replacement deposits; (2) injection pegmatites and pegmatitic metamorphic segregations that could contain deposits of metallic or radioactive elements; (3) foliated and gneissic granitoid rocks that could contain disseminated deposits of metals, radioactive elements, or rare-earth elements; (4) quartz veins or other vein-type deposits that result from hydrothermal mineralizing systems; (5) layered greenstone units of Pelona Schist that could contain massive-sulfide deposits; and (6) Quaternary sand and gravel deposits that could contain placer accumulations of precious metals, radioactive minerals, or rare-earth elements. Our examination of rocks within the Raywood Flat Roadless Areas suggests that, although small-scale mineral occurrences may exist locally, these generalized geologic environments probably have not been the sites of large-scale mineralization.

Contact metasomatic environments.—Metasedimentary pods that are scattered throughout gneissic plutonic rocks of the study area provide potential sites for metallic mineralization by contact metasomatism. Elsewhere in the eastern San Bernardino Mountains, in areas such as the Tip Top Mountain, Holcomb Valley, and Bear Valley districts about 20 mi north of the study area, gold and tungsten have been discovered in Paleozoic quartzite, metaquartzite, and marble that have been intruded by late Mesozoic plutons. Adjacent to the Raywood Flat roadless areas, small-scale metallic mineralization resulting from contact metasomatism has been inferred by Cox and others (1983a) for parts of the San Gorgonio Wilderness that contain small bodies of marble. In the study area, north of the Mill Creek fault and between the Mill Creek and Mission Creek faults, small bodies of metasedimentary rock are scattered sparsely throughout the foliated and gneissic plutonic rocks. The metasedimentary rock consists mainly of biotite-sillimanite-garnet schist that does not show obvious signs of mineralization. Except for several small marble lenses that occur in the vicinity of the Mill Creek mine (fig. 2, loc. 3), marble and metaquartzite are rare in the study area. In the marble bodies at the Mill Creek mine we observed scattered small-scale tactite zones containing the tungsten mineral scheelite. This was the only evidence of mineralization related to contact-zone metasomatism that we observed in the roadless areas.

Pegmatitic environments.—Lenses and veins of pegmatite that occur locally within the study area provide potential sites for occurrences of metallic, rare-earth, or radioactive elements. A known example of such mineralization is the abandoned workings near Alger Creek in the further planning area (the St. Patrick mine, fig. 2, site 2); here, a low-grade occurrence of the uranium-bearing mineral uranothorite has been reported by Hewett and Stone (1957). The uranothorite is disseminated in pegmatitic lenses that occur in granitic gneiss. Nearby, pegmatitic segregations also occur within biotite-rich compositionally layered Precambrian gneiss. In their study of the adjacent San Gorgonio Wilderness, Cox and others (1983a) cited evidence from geochemical and aeroradioactivity surveys (Pitkin and Duval, 1981) and concluded that any undiscovered occurrences of radioactive elements or rare-earth elements within pegmatitic segregations or veins in these rocks are likely to be small scale and insignificant. This conclusion is applicable not only to the San Gorgonio Wilderness but also to adjacent areas that include the Raywood Flat further planning area (B5-187) north of Mill Creek. Elsewhere in the study area, stream-sediment geochemical anomalies for elements like lanthanum, yttrium, thorium, and beryllium suggest that some stream drainages locally may contain small-scale pegmatitic mineral occurrences; however, we observed no evidence of mineralization in the pegmatitic lenses that we examined.

Porphyry occurrences in granitoid environments.—Foliated and gneissic granitoid rocks within the study area provide potential sites for disseminated occurrences of metallic elements. However, the petrology and intrusive setting of these plutonic rocks differs from plutonic rocks elsewhere that have produced disseminated-mineral deposits (for example, copper- and molybdenum-porphyry deposits; occurrence models for disseminated-mineral deposits are discussed by Cox, 1982, Ludington, 1982, and Theodore, 1982). In the Raywood Flat Roadless Areas, we did not observe textural and petrologic features that characterize porphyry-metal deposit types; we also did not observe evidence indicating that disseminated metals might be present (extensive zones of alteration or oxidation, or zones of rock containing disseminated native metals or metallic sulphides).

Vein and replacement environments.—Foliated and gneissic granitoid rocks within the study area are potential sites for hydrothermal veins or replacement bodies containing metallic mineral occurrences. However, in the rocks we examined, we did not observe direct evidence for these types of mineralizing systems (for example, surficial evidence such as extensive quartz-vein networks, iron- or copper-stained rock or gossans, alteration zones, concentrations of metallic ore minerals in veins). Stream-sediment geochemistry suggests that some drainages in the eastern part of the study area have been sites where base metals have been concentrated, probably resulting from vein-type mineralizing systems. However, we could not examine the crystalline rocks in most of these drainages; thus, the source or geologic setting of the metallic elements have not been confirmed.

In the eastern San Gabriel Mountains, 45 mi west of the study area, gold- and tungsten-bearing quartz and carbonate veins occur in structurally low parts of the upper plate of the Vincent thrust; gold-bearing veins occur in the Pelona Schist of the lower plate (Gay and Hoffman, 1954; Ridenour and others, 1982; Zilka and Schmauch, 1982; Morton and others, 1983; Cox and others, 1983b) In the study area, the Vincent-Orocopia thrust and associated upper and lower plate rocks crop out in the headwaters of San Gorgonio River. We did not observe extensive quartz-vein networks in these rocks; moreover, our stream-sediment geochemistry survey did not detect gold or tungsten in this vicinity. By contrast, in the San Gabriel Mountains, stream-sediment geochemical anomalies for gold and tungsten were identified by Morton and others (1983) and by Cox and others (1983b) in drainage basins containing known or inferred tungsten and gold occurrences.

Greenstone environments.—Mafic greenstone deposits of Pelona Schist that crop out in the recommended wilderness area provide potential sites for massive-sulfide occurrences. These mafic rocks represent basaltic materials that have been metamorphosed to greenschist-facies mineralogy. If the greenstone layers represent ocean-floor basalt flows, they might have formed in environments conducive to massive-sulfide mineralization. We did not observe evidence of metallic minerals in outcrops of greenstone, and stream-sediment geochemistry samples from drainages containing greenstone did not contain geochemical anomalies for base metals. Moreover, the greenstones possibly originated as submarine basaltic tuff, an idea favored by Ehlig (1968; 1981, p. 271); under these conditions the rocks probably would not have been hosts for ocean-floor deposits of sulfide metals.

Placer deposits.—Placer mining has not occurred in the study area historically; however, sand and gravel deposits, including younger alluvial deposits as well as dissected older deposits, provide potential sites for placer accumulations of precious metals, radioactive minerals, or minerals containing rare-earth elements. We obtained numerous geochemical samples of fresh sediment deposited by active streams; however, none of these samples provides geochemical evidence of placer accumulations, and none of the stream drainages contains large amounts of alluvial fill that would provide extensive sites for larger placer deposits. We did not sample the older gravel units and thus have not evaluated these gravels as a potential placer resource; however, panned-concentrate fractions from stream-sediment sites adjacent to large areas underlain by older gravel deposits generally do not have anomalous elemental abundances. Bodies of sand and gravel within the study area most likely are not sites for placer-type mineral occurrences.

Nonmetallic mineral resources

Sand and gravel deposits and granitoid rocks that occur in the Raywood Flat Roadless Areas provide possible sources of aggregate and riprap for industrial use. Except for older-gravel deposits in the vicinity of Raywood Flat, alluvial deposits throughout most of the roadless areas are thin and limited in extent. The extensive gravel deposits in the vicinity of Raywood Flat are relatively inaccessible and are far from available markets. Foliated and gneissic granitoid rocks for the production of crushed aggregate, decomposed granite, and riprap are abundant within the study area. Bodies of marble (metamorphosed limestone and dolomite) that occur at the Mill Creek mine (fig. 2, loc. 3) are possible sources of lime and magnesium for cement and for other industrial and manufacturing applications, and also are sources of crushed rock for aggregate, roofing granules, and riprap.

Geochemistry

A reconnaissance geochemical survey of stream sediments in the Raywood Flat Roadless Areas 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. Two samples of sandy stream alluvium were collected from each of 56 sample sites within the study area: a bulk-sediment sample, and a panned-concentrate rich in heavy minerals. The results of the geochemical survey are discussed by Matti and Cox (1983).

The patterns of chemical composition determined by the stream-sediment geochemical survey of the Raywood Flat Roadless Area do not indicate significant large-scale mineralization within the study area. Few elemental values are anomalous with repect to the average geochemical background for the roadless areas; most of the analyses fall within ranges that are reasonable for nonmineralized crystalline rocks and derivative stream sediments. Geochemical evidence thus is compatible with geologic evidence: both reconnaissance techniques suggest that significant occurrences of metallic or nonmetallic minerals probably do not occur in the Raywood Flat Roadless Areas.

Radioactive and rare-earth elements and transition metals

Anomalous and elevated values for uranium, thorium, lanthanum, niobium, yttrium, and zirconium occur in stream-sediment samples throughout the Raywood Flat Roadless Areas, although most commonly in the further planning area (B5-187) north of the Mission Creek and Mill Creek fault zones. For example, uranium was detected in higher-than-average amounts in several bulk-sediment samples north of the Mission Creek fault zone and especially north of the Mill Creek fault zone, but south of the Mission Creek fault zone elevated values for uranium occur only in isolated samples. The distribution of these elements seems to be related to (1) the overall composition of foliated and gneissic plutonic rocks and (2) the distribution of pegmatitic veins and segregations. Foliated and gneissic biotite-bearing plutonic rocks north of the Mission Creek fault zone generally are more leucocratic and more silicic in composition than biotite-hornblende-bearing foliated and gneissic plutonic rocks south of this fault zone. Moreover, pegmatite dikes and metamorphic segregations are common throughout the crystalline rocks north of the Mission Creek fault zone, but are only abundant locally south of this fault zone. We believe these geologic contrasts give rise to the geochemical contrasts for radioactive and rare-earth elements that exist in the Raywood Flat Roadless Areas.

Elevated or anomalous values for radioactive and rare-earth elements and transition metals probably reflect higher-than-average background levels for these elements rather than local concentrations of ore minerals. These elements probably occur in common non-ore rock-forming minerals like sphene, zircon, apatite, allanite, and epidote that we have observed in thin sections of the crystalline rock units. The abundance and chemical composition of these non-ore minerals vary in different rock types from place to place within the study area; these variations probably account for higher-than-average values of rare-earth elements, radioactive elements, and transition metals that occur in some drainages.

Metallic elements

In some panned-concentrates, metallic elements were detected in amounts that exceed background values; these elevated values indicate that local mineral concentrations may exist in the study area. The origin of the geochemical anomalies is unknown. However, their geologic sources probably are limited in size and distribution because the anomalies are not large and because they generally do not show systematic geographic patterns or clustering. The anomalies probably are not related to significant mineral occurrences; instead, they probably represent local geologic sources such as quartz veins, injection pegmatites and pegmatitic segregations in the layered gneiss, or various kinds of igneous dikes.

One example of metallic anomalies that we have attributed to isolated geologic point sources include higher-than-average values for chromium, cobalt, nickel, and copper that occur in panned-concentrate samples and to a lesser degree in bulk-sediment samples from several streams that drain the further planning area (B5-187) north of Mill Creek. A particularly anomalous sample collected from Skinner Creek (fig. 2, site SG-08) contains 700 ppm (parts per million) chromium, 50 ppm cobalt, and 500 ppm nickel in the bulk-sediment fraction. These conspicuous anomalies suggest a mafic or ultramafic igneous source. Numerous dikes of fine-grained mafic rock are well exposed in roadcuts along Highway 38, and some of them crop out upstream from the sample site on Skinner Creek. We did not study the dikes in detail, but it is possible that they contain disseminated chromite and sulfide minerals and thus are reponsible for the chromium-cobalt-nickel anomaly on Skinner Creek as well as for small copper anomalies that occur in two adjacent drainages.

Stream-sediment samples from the east end of the recommended wilderness (A5-187) contain geochemical anomalies which indicate that mineralizing processes have taken place within the crystalline rocks of several adjacent stream drainages. Geographic clustering of these anomalies suggests that the area drained by the streams forms a distinct zone where metal-concentrating processes not only have occurred but have been sufficiently intense to be detected consistently by the reconnaissance geochemical method. Anomalous or higher-than-background values for several metals occur in panned concentrates from the following stream-sediment localities (fig. 2): RW-31 (1,500 ppm lead); RW-36 (700 ppm arsenic); RW-38 (1,500 ppm lead, 10,000 ppm barium, 500 ppm copper, 70 ppm molybdenum, 30 ppm bismuth, 100 ppm cobalt; anomalous lead and barium also occur in the bulk-sediment sample from this locality); RW-39 (150 ppm tin); RW-40 (500 ppm lead, 100 ppm tin); RW-41 (700 ppm lead, 100 ppm molybdenum, 20 ppm bismuth, 70 ppm cobalt); and RW-42 (700 ppm lead, 150 ppm molybdenum). Steep brush-covered topography prevented our examination of much of the bedrock in the drainages sampled by RW-31, -36, -38, -39, -40, -41, and -42. Consequently, we have no direct evidence for the type or scale of mineralization that may have occurred in this vicinity and can only infer that mineral occurrences exist here. Metallic mineralization here may reflect occurrences of minerals in disseminated concentrations (porphyry mineralization). However, the lead-barium-bismuth-copper-molybdenum suite from sample RW-38, together with tin, molybdenum, lead, and arsenic in the other samples, is a suite of elements commonly found in veins and replacement deposits of hydrothermal origin. The barium anomaly in RW-38 probably is derived from barite, a common gangue mineral in lead-bearing hydrothermal veins. Thus, we suspect that this part of the recommended wilderness contains small-scale hydrothermal quartz-barite veins containing base metals.

Geophysical surveys

Two aerial magnetic surveys of the southern San Bernardino Mountains were flown in 1978 and 1979 as part of mineral resource investigations for the San Gorgonio Wilderness and Raywood Flat Roadless Areas (J. A. Pitkin, J. S. Duvall, and H. W. Oliver, U.S. Geological Survey, unpub. data, 1978; U.S. Geological Survey, 1979). The magnetic data have been analyzed by H. W. Oliver (in Cox and others, 1983; unpub. data, 1983). Rocks within the Raywood Flat study area are overlapped by both aerial surveys.

The airborne magnetic surveys measured variations in the total intensity of the Earth's magnetic field over the Raywood Flat Roadless Areas and vicinity. Slight variations in magnetic intensity are caused by uneven distribution of iron-rich minerals in rocks at or near the Earth's surface. Therefore, a magnetic survey can help identify concentrations of iron-rich minerals or other minerals that may be associated with deposits of iron ore. The magnetic patterns and anomalies within the study area are not unexpected for the kinds of crystalline rocks exposed here, and there is no aeromagnetic evidence for mineralization within the Raywood Flat Roadless Areas.

Gravity measurements in the Raywood Flat Roadless Areas were made in 1981 to complete a larger gravity survey of the San Bernardino 1° by 2° quadrangle (Tang and Ponce, 1982; Biehler and others, 1983). The gravity data provide no evidence for mineralization within the study area.

MINING DISTRICTS AND MINERALIZATION

Personnel from the U.S. Bureau of Mines studied mineral resources of the Raywood Flat further planning area (B5-187) in 1982. County mining records were examined to determine claim locations. Library research was done to provide historical, geologic, and mineral resource data. Field studies included examining and sampling mines and prospects. A total of eight lode samples were taken from mineralized structures; five placer samples were taken from gravel deposits.

Previous studies include an unpublished investigation in 1954 by the Defense Minerals Exploration Administration (DMEA) of marble deposits at the Mill Creek mine. This investigation was in response to a request by Robert Burns and others, claimants of the Mill Creek mine, for DMEA assistance to explore tungsten occurrences at the mine. A geologic investigation of the St. Patrick uranium-thorium mine was conducted by Hewett and Stone (1957). A mineral resource study of the adjacent San Gorgonio Wilderness included an examination of the St. Patrick and Mill Creek mines (Zilka, in Cox and others, 1983).

History and production

The Mill Creek mining district covers Mill Creek Canyon and the northern half of the further planning area. The mineral commodities produced from this district consist of ground marble (possibly used for manufacture of lime) from the Mill Creek mine, uranium-thorium ore from the St. Patrick mine, and construction stone from the Cable mine a few miles west of the study area. The Bear Valley mining district, 9 miles north of the study area, yielded placer gold and limestone.

The first mining in the Mill Creek district occurred in 1888 when H. G. Cable quarried dimension stone from a sandstone formation (the Potato Sandstone of Vaughan, 1922) on Mill Creek about 4 mi west of the study area. This stone was used in the construction of buildings in Redlands (about 10 mi west of the study area) and Los Angeles. In 1897, Mill Creek Canyon was prospected for gold, but no deposits were found (Redlands Daily, October 8 and 16, 1897). In May 1907, the Mill Creek marble deposit was claimed by George Burris. It was relocated several times, and by 1942 it had been acquired by the Mill Creek Limestone Company. That company operated the mine in 1942 and 1943 (Logan, 1947, p. 292). The marble was trucked to a 15-ton-per-hour grinding plant 8 mi east of Redlands on Highway 38. It is not known how the ground marble was used. A uranium-thorium occurrence on the north side of Mill Creek, the St. Patrick mine, was located in 1953 by Earl Gilliam, Jr. and others; numerous uranium claims were located in this vicinity during the 1950's. Peat has been dug from deposits in the Burro Flats area, 1 mi south of the study area. Intermittent peat production has occurred since 1956, yielding 1,000 yd^3 per month in 1960 (California Division of Mines, 1960, unpub. data).

Mining claims

Since 1893, about 70 placer claims and 160 lode claims have been filed within the Raywood Flat further planning area, and 60 placer claims and 170 lode claims have been located near the area. There are no active claims, patented claims, or mineral leases in the further planning area.

Mines and prospects

Mines and prospects examined in the Raywood Flat further planning area are described in table 1.

Mill Creek mine.—Marble has been quarried at the Mill Creek mine on the north wall of Mill Creek Canyon (fig. 2, site 3). The workings are located in the largest and easternmost of three lenticular marble bodies enclosed by granitic gneiss and intruded by monzogranite. The marble is white and crystalline, and locally hosts narrow, discontinuous garnet-epidote tactite pods which contain minor scheelite.

St. Patrick mine.—Three uranium- and thorium-bearing pegmatite bodies that occur in granitic gneiss are exposed in bulldozer cuts at the St. Patrick mine (fig. 2, site 2). The pegmatite lenses probably formed as metamorphic segregations within the granitic gneiss. They consist of reddish-brown microcline and quartz, with small amounts of uranothorite. The lenticular bodies are en echelon, and their northeast strike and southeast dip are conformable with foliation of the granitic gneiss. The dikes measure a maximum of 3.5 ft thick and 48 ft long. Similar pegmatitic dikes and lenses occur in the unit of biotite-rich Precambrian gneiss, and also in the units of monzogranite and quartz monzodiorite. The Mountain Home prospect (fig. 2, site 1) is developed in pegmatite that cuts the porphyritic quartz monzodiorite unit. Only the pegmatites at the St. Patrick mine are known to contain radioactive minerals.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Geologic, geochemical, and geophysical studies within the Raywood Flat Roadless Areas, together with an investigation of mines and prospects within the further planning area, resulted in our identification of nometallic mineral resources at a marble mine in the further planning area, and in our recognition of a small area in the recommended wilderness that has moderate potential for base-metal resources. Except for these two areas of identified and suspected resources, we did not observe indications of resource potential elsewhere in the Raywood Flat Roadless Areas. These mineral resource assessments are based on the following considerations:

(1) Geologic mapping within the study area revealed several geologic environments potentially favorable for metallic and nonmetallic mineralization. However, we did not observe evidence of significant mineral occurrences that might have formed in these environments.

(2) Chemical analyses from 56 bulk-sediment and panned-concentrate samples indicate that elemental abundances generally fall within background ranges expected for nonmineralized rocks. In the recommended wilderness (A5-187), a small area having geochemical anomalies is an exception to this generalization.

(3) Aeromagnetic patterns and gravity data do not indicate concentrations of magnetic minerals or minerals having high or low density.

(4) Prospecting activities have been limited and short lived, production has been restricted to small amounts of marble and low-grade uranium ore from abandoned workings in the further planning area (B5-187), and no large deposits of metallic, nonmetallic, or radioactive minerals have been discovered. In view of extensive prospecting conducted in the San Bernardino Mountains for mineral deposits similar to those of the Holcomb Valley and Bear Valley districts, the absence of significant historical workings in the vicinity of the Raywood Flat Roadless Areas reflects the generally low mineral resource potential of rocks in this area.

Discussion of base-metal potential

Geochemical anomalies for base metals were detected in several small streams that drain an area in the eastern part of the recommended wilderness (fig. 2, A5-187). Anomalies for lead, molybdenum, copper, tin, bismuth, cobalt, barium, and arsenic occur in the panned-concentrate fractions of stream-sediment samples from several drainages that occur in this part of the study area. Because the terrain is inaccessible and covered with dense brush, we could not examine all the bedrock in these drainages; hence, the origin of the metallic anomalies is unknown. Thus, although we infer that mineral occurrences exist in the drainages, we have little data on which to base an estimate of their extent and quality. The mineral occurrences probably are in hydrothermal quartz-barite veins or in small-scale disseminated concentrations.

The geochemical evidence suggests that there is a high probability that mineral occurrences of some kind exist in the drainage basins. However, there is only low probability that the occurrences are large scale; more likely, they are small scale and scattered. This interpretation is based on three arguments:

(1) Geologic setting.—Although we were not able to examine all the rocks in this area, those that we did examine are similar to other foliated and gneissic granitoid rocks in this part of the recommended wilderness that occur in the upper plate of the Vincent-Orocopia thrust. Here and elsewhere in the upper plate, we did not observe extensive quartz-vein networks or large areas of stained or altered rock that would provide surficial evidence for large-scale base-

metal mineralization in hydrothermal veins or disseminated concentrations.

(2) Geochemical evidence.—The stream drainages that yielded anomalous metallic values are fairly small, and the geochemical anomalies themselves are not large. Therefore, any mineral occurrences containing base metals also are likely to be small and scattered.

(3) Base-metal occurrences elsewhere in the region.—The probable scale of mineral occurrence in the area of geochemical anomalies can be estimated crudely by analogy with what is known about metallic mineral occurrences in similar geologic terranes elsewhere in southern California. Rocks similar to those in the recommended wilderness occur in the eastern San Gabriel Mountains, 45 mi west of the Raywood Flat Roadless Areas. A comparison between the two areas is valid not only because rocks in the upper plate of the Vincent-Orocopia thrust are similar in both areas, but because this geologic terrane probably once was continuous between the southeastern San Bernardino Mountains and the eastern San Gabriel Mountains and subsequently was dismembered and offset by strike-slip displacements on various fault systems in this part of southern California. In the eastern San Gabriel Mountains, large-scale mineral deposits containing lead, copper, molybdenum, and tin have not been discovered, although isolated small-scale occurrences of base metals have been identified and interpreted as accessory metals associated with tungsten and gold. Tungsten and gold occurrences in quartz and carbonate veins have been the targets of mineral exploration in the San Gabriel Mountains and have produced small amounts of ore, but base-metal occurrences have not produced any ore (Gay and Hoffman, 1954; Ridenour and others, 1982; Zilka and Schmauch, 1982). Gold and tungsten were not detected in the Raywood Flat stream-sediment samples that contain base metals. Using previous experience in the eastern San Gabriel Mountains as a guide, it is unlikely that large-scale mineral occurrences containing base metals exist in rocks underlying the Raywood Flat Recommended Wilderness.

Based on these three arguments, we conclude that bedrock in the area of geochemical anomalies has moderate potential for base metals in hydrothermal veins or in disseminated occurrences. The potential is moderate because two parameters are satisfied by our studies: (1) geologic and geochemical data provide suggestive evidence that mineral-concentrating processes have taken place; and (2) we recognize some conditions of an occurrence model for the type of metallic mineralization (hydrothermal quartz-barite veins), even though evidence for these conditions is fragmentary or ambiguous. Although we assign moderate resource potential to this area (fig. 2), any undiscovered mineral occurrences that might exist in this area probably are not important mineral deposits. Moreover, the delineated zone having moderate resource potential probably is much greater in size than the area actually containing mineral occurrences, as the boundaries are arbitrary and were drawn to enclose all drainage basins that contain stream-sediment geochemical anomalies.

Discussion of nonmetallic and energy resources

The Mill Creek mine has about 5.5 million tons of demonstrated marginal reserves of marble suitable for lime, chemicals, cement, and construction material; however, nearly all the marble reserves are outside the further planning area (B5-187). Although marble has been produced from this deposit and possibly used for lime, we have classified the reserves as marginal because of their remote location and poor accessibility. Similar or better deposits elsewhere are closer to major markets, are more accessible, and therefore incur lower transportation costs.

Granitic rock and deposits of sand and gravel in the study area are suitable for construction uses, but similar or better deposits elsewhere in southern California are closer to major markets. Consequently, those in the study area are subject to higher transportation costs.

Pegmatite and uranium totalling less than 10 tons was shipped from the St. Patrick mine in 1954 (Hewett and Stone, 1957), at about the same time that other small uranium deposits, including the Thum Bum claim near Big Bear Lake (Troxel and others, 1957, p. 671), were being developed elsewhere in the eastern San Bernardino Mountains. Samples of the pegmatite that we analyzed contained 0.019 and 0.002 percent uranium oxide (U_3O_8) and 0.159 and 0.35 percent thorium. By comparison with most commercial uranium deposits being mined today that contain at least 0.1 percent U_3O_8, the uranothorite-bearing occurrences at the St. Patrick mine are small and low grade. The absence of significant radioactive-mineral resources at the St. Patrick mine is corroborated by an airborne radiometric survey (Pitkin and Duval, 1981), which did not detect abnormal levels of gamma radiation in this vicinity.

Recommendations for future studies

If additional mineral resource studies are conducted in the Raywood Flat Roadless Areas, we recommend that the area having moderate potential for base-metal resources be examined more thoroughly to determine the extent and quality of mineral occurrences that might exist there. Detailed mapping and followup geochemical studies of bedrock and stream sediments in accessible areas are necessary to confirm the presence or absence of mineral occurrences and to locate the areas that are the sources for the metallic anomalies.

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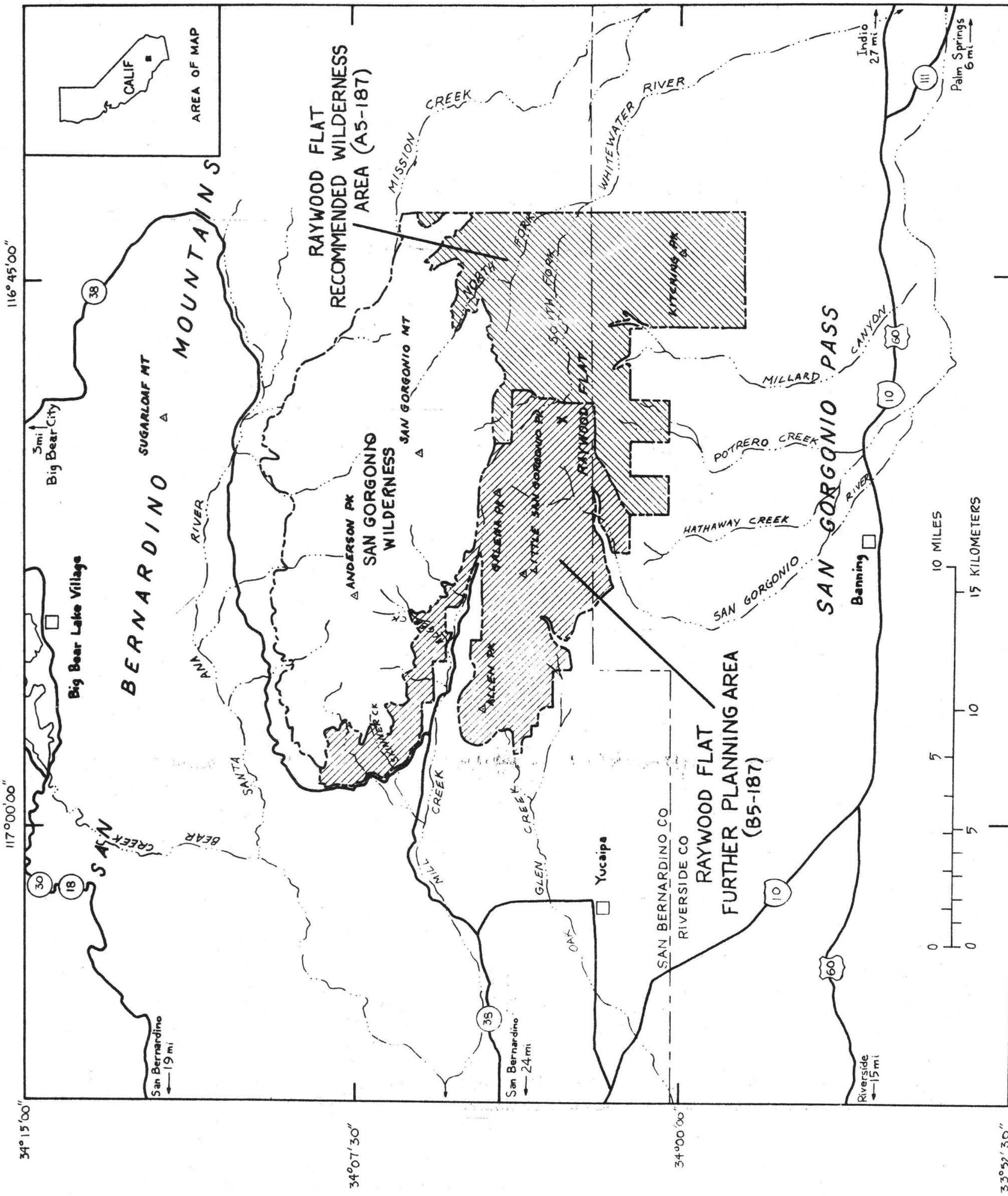

Figure 1.--Index map showing location of the Raywood Flat Roadless Areas (further planning area B5-187 and recommended wilderness area A5-187), San Bernardino and Riverside Counties, Calif.

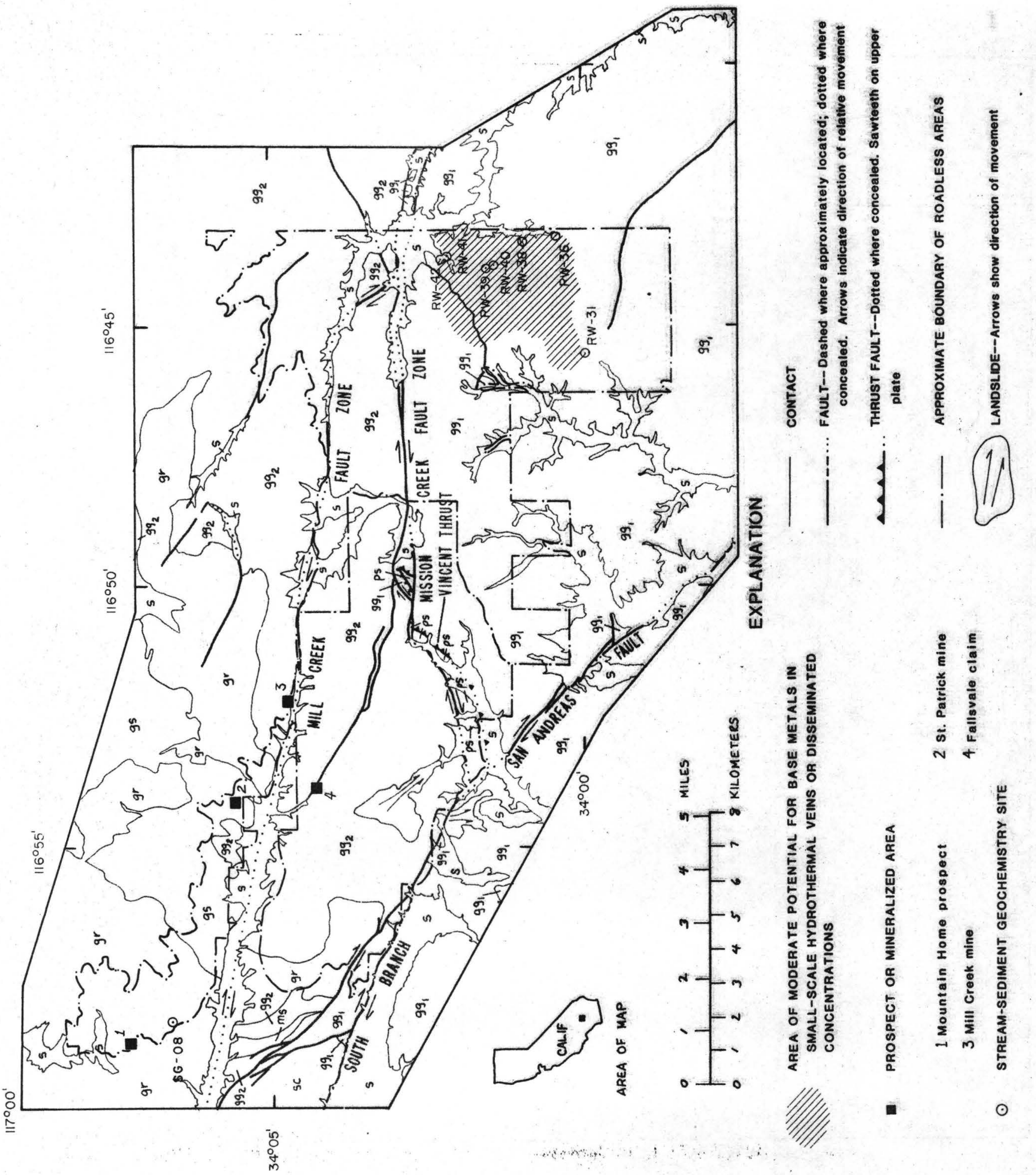

Figure 2.--Raywood Flat Roadless Areas, showing zone with mineral resource potential, mines and prospects, and selected stream-sediment geochemistry sites. Geology simplified from accompanying mineral resource potential map. s, surficial sedimentary deposits, including younger alluvium, older gravel deposits, and glacial deposits; sc, sandstone and conglomerate; gr, granitoid rocks; ps, Pelona Schist; gg_1, granitic gneiss and gneissic granite south of the Mission Creek fault zone; gg_2, granitic gneiss and gneissic granite north of the Mission Creek fault zone; ms, metasedimentary rock; gs, gneiss and schist.

Table 1.--Mines and prospects in the Raywood Flats further planning area B5-187

Location No.	Name	Summary	Production and workings	Sample data and resources
1	Mountain Home prospect	A pegmatite dike in porphyritic quartz monzodiorite is 2.7 ft thick, strikes N. 63° E., dips vertically, and is composed of 80 to 90 percent pink and white feldspar, 10 percent quartz, and minor biotite.	Prospect cut	One sample across dike assayed no appreciable metals.
2	St. Patrick mine	Uranothorite occurs in three reddish-brown, microcline- and quartz-rich pegmatite dikes conformable with foliation in gneiss. The lenticular dikes are en echelon, strike from N. 66° to 76° E., dip 28° to 34° SE., and measure a maximum of 3.5 ft thick and 48 ft long. A 1.7-ft-thick zone in the 48-ft dike is radioactive.	Less than 10 tons of mineralized material has been removed (Hewett and Stone, 1957, p. 104). Workings include two bulldozer cuts and one prospect pit.	Two samples across the 1.7-ft-thick radioactive zone in the dike assayed 0.019 and 0.002 percent U_3O_8 and 0.159 and 0.35 percent thorium. Three samples representing the three lenses taken by Zilka (in Cox and others, 1983) averaged 0.02 percent U_3O_8.
3	Mill Creek mine	Three lenses of marble occur within gneissic rocks intruded by monzogranite. The lenses parallel foliation, striking north-northeast and dipping from 32° to 55° NW. A tactite zone averaging 0.5 ft thick occurs in the marble. From east to west, the marble lenses are 64, 48, and 27 ft thick and 1,800, 1,100, and 500 ft long (Zilka, in Cox and others, 1983). At depth the marble may be contaminated and completely assimilated by monzogranite.	13,600 tons of marble have been quarried (Zilka, in Cox and others, 1983). Workings include three large open cuts and an adit 18 ft long.	A random chip sample from the marble contained 82.1 percent $CaCO_3$, 1.2 percent SiO_2, 1.46 percent Al_2O_3, 0.06 percent Fe_2O_3, 0.35 percent MgO, 0.03 percent K_2O, and 0.02 percent Na_2O. Of three samples across tactite, two assayed 0.26 and 0.07 percent WO_3. There are about 5.5 million tons of marginal marble reserves. Nearly all of the marble reserves lie outside the study area.
4	Fallsvale claim	A zone of black muscovite gabbro is intruded into gneiss.	None	A random chip sample from gabbro assayed no appreciable metals.