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MINERAL RESOURCE POTENTIAL OF THE SILL HILL, HAUSER, AND CALIENTE ROADLESS AREAS, SAN DIEGO COUNTY, 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 be submitted to the President and the Congress. This report discusses the results of mineral surveys of the Sill Hill (5-304), Hauser (5-021), and Caliente (5-017) Roadless Areas, Cleveland National Forest, San Diego County, California.

SUMMARY

The Sill Hill, Hauser, and Caliente Roadless Areas comprise approximately 20,000 acres in the Cleveland National Forest, San Diego County, Calif. (fig. 1). Geological and geochemical investigations have been conducted by the U.S. Geological Survey, and a survey of mines and prospects was made by the U.S. Bureau of Mines to evaluate the mineral resource potential of the study areas.

The Sill Hill, Hauser, and Caliente Roadless Areas lie within the Peninsular Ranges batholith of southern California, and they have similar geologic settings and histories. No significant mineral resources were found in any of the three areas and all three have generally low potential for the occurrence of mineral resources. Parts of the Sill Hill Roadless Area have low potential for gold, tungsten, nickel, and feldspar. The Hauser Roadless Area has low potential for resources of potash feldspar. The Caliente Roadless Area has low potential for tourmaline, beryl, quartz, and possibly other specimen minerals and gemstones. In general, none of these areas have potential geothermal, hydrocarbon, or nuclear energy resources. Although the Caliente Roadless Area is located 3,000 ft (920 m) north of an area of hot springs, there is no evidence of hot springs activity within the roadless area and potential for geothermal resources is probably low.

INTRODUCTION

The Sill Hill, Hauser, and Caliente Roadless Areas consist of 6,500, 7,600, and 5,900 acres, respectively, of the Cleveland National Forest, San Diego County, California. The climate of San Diego County is Mediterranean, with hot dry summers and mild rainy winters. Precipitation is derived chiefly from onshore winds from the Pacific Ocean and occurs typically during the winter months as rain, with snow only in the high mountains. The three roadless areas are located within the Cretaceous Peninsular Ranges batholith of southern California, and they have similar geologic settings and mineral potential. Total relief in the areas ranges from about 2,200 to 3,400 ft. Major drainages are Boulder Creek (Sill Hill), Cottonwood Creek (Hauser), and Agua Caliente Creek (Caliente). The roadless areas generally are characterized by rugged, chapparal-covered topography. Pine, fir, and oak trees are common at elevations above 4,000 ft (1,200 m). Access to the areas is provided by light duty and unimproved roads off of State Highways 76, 79, 78, 8, and 94 (fig. 1).

Present and Previous Studies

This report draws heavily upon studies made in recent years on the geology of the Peninsular Ranges batholith by Todd (1977a, b; 1978a, b; 1979; 1980; and 1982) and by Hoggatt and Todd (1977). This work has been summarized by Todd and Shaw (1979). Weber (1963) compiled a very useful report on the geology and mineral resources of San Diego County in which he catalogued all known mineral occurrences of possible significance. Everhart (1951) studied the geology of the 15' quadrangle in which the Sill Hill Roadless Area occurs. Studies by Jahns (1954a, b; and 1955) and Jahns and Wright (1952) are very useful references on pegmatite deposits of the region.

The U.S. Geological Survey carried out geologic mapping and a regional geochemical survey in 1979 and 1980. The U.S. Bureau of Mines evaluated mineral resources by searching pertinent geological and mining publications as well as U.S. Bureau of Land Management, Forest Service, and Bureau of Mines files and records. Known mines, prospects, and mineralized localities were examined in 1981 by Bureau of Mines personnel and sampling and mapping were done where warranted.

Geologic Setting

The Sill Hill, Hauser, and Caliente Roadless Areas lie within the Cretaceous Peninsular Ranges batholith of southern California. The segment of the Peninsular Ranges batholith which lies within San Diego County accounts for approximately 1/20 of the total length of the batholith; the width of the segment here, 50 mi (80 km), is representative of the entire batholith. The western side of the batholith is concealed by Upper Cretaceous to lower Pleistocene(?) sedimentary rocks in western San Diego County. The original eastern extent is uncertain, although the batholith probably extended at least as far east as northwestern Sonora, Mexico, prior to offset by the San Andreas fault, beginning in Miocene time (Silver and others, 1979).

Batholithic rocks in San Diego County have been divided into a sequence of older plutonic rocks that formed contemporaneously with regional deformation (syntectonic sequence) and a sequence of later plutonic rocks that formed late in, or following, regional deformation (late- to post-tectonic sequence) (Hoggatt and Todd, 1977; Todd, 1977-82; Todd and Shaw, 1979). Uranium-lead zircon ages of selected rocks from the western part of San Diego County, rocks which we consider to belong to the syntectonic sequence, range from 120 to 105 m.y., whereas ages of two post-tectonic plutons are less than 100 m.y. (Silver and others, 1979). The older, syntectonic sequence was further subdivided into two belts of plutonic rocks which were derived by melting of different source materials at depth, a western belt derived from igneous source materials (I-type) and an eastern belt derived from sedimentary source materials (S-type) (Todd and Shaw, 1979).

Field relations indicate that plutons of the western part of the batholith were emplaced beneath a volcanic pile, the Lower Cretaceous Alisitos Formation in Northern Baja California and the Santiago Peak Volcanics of Late Jurassic and Early(?) Cretaceous age in San Diego County (Silver and others, 1963; Schoellhamer and others, 1981). The eastern plutons, which include plutons of middle Cretaceous age, were emplaced at greater depths, as indicated by the higher grade of metamorphism of the eastern wallrock screens and the occurrence with them of highly metamorphosed plutonic gneisses. These geologic relations are interpreted as a volcanic-plutonic-metamorphic arc which remained active from Late Jurassic to middle Cretaceous time. Sedimentary aprons, in part volcaniclastic, which had accumulated to the east of the early arc volcanoes were intruded and engulfed less than 100 m.y. ago by plutons that show little deformation (late- to post-tectonic sequence).

SILL HILL ROADLESS AREA

The Sill Hill area consists of 6,500 acres within the Descanso Ranger District of the Cleveland National Forest, San Diego County, California. It is bordered by Cuyamaca Rancho State Park on the east and by Boulder Creek Road on the west (fig. 2). The study area includes much of the western slope of the Cuyamaca Mountains. Elevations range from 2,830 ft (862.6 m), where the western boundary crosses Boulder Creek, to 6,200 ft (1,890 m) near the eastern boundary, about 0.7 mi (1.3 km) north-northwest of Cuyamaca Peak. Cuyamaca Peak lies within the state park and, at 6,512 ft (1,984.9 m), is the highest peak in the region. Precipitation ranges from about 25 in (63.5 cm) annually at lower elevations to over 35 in (88 cm) at higher elevations (Merriam, 1951, p. 119).

GEOLOGY AND GEOCHEMISTRY PERTAINING TO MINERAL RESOURCE ASSESSMENT

Geology

The Sill Hill Roadless Area is underlain by narrow, steeply dipping granitic plutons of both I- and S-type that are greatly elongated in a north-south direction, by the western margin of the gabbroic complex (Cuyamaca Gabbro) in the Cuyamaca Mountains, and by small remnants of prebatholithic wall rocks. The most important factor influencing localization of mineralization in the Sill Hill Roadless Area was Cretaceous syntectonic batholithic emplacement which controlled the strong layering of the plutonic rocks and wallrock inclusions. Isoclinally folded quartz veinlets in these rocks similar to those found in the Julian mining district (Donnelly, 1934) indicate that quartz deposition and(or) segregation and mineralization began when metamorphic folding was still occurring. In the Sill Hill area, leucocratic and pegmatitic dikes and quartz veins are most abundant in the most strongly foliated (most deformed) plutons; for example, the quartz diorite of East Mesa and the granodiorite of Cuyamaca Reservoir (granitic rock classification of Streckeisen, 1973). Faults formed readily in these layered plutons beginning at a late stage of batholithic intrusion and silicic magmas and residual hydrothermal fluids moved through faults and along layering. Gouge zones were preferred sites for deposition of quartz and for mineralization. Most large gouge zones, those wider than 6 in (15 cm), are surrounded and permeated by products of hydrothermal alteration—epidote, chlorite, potassium feldspar, and clays. The Cuyamaca Mountains fault zone crosses the roadless area from south to north. The zone consists of short, 3,300-ft (1-km) en echelon, steeply dipping faults which cut Cretaceous batholithic rocks and fanglomerate that was deposited on the old erosion surface that lies west of, and at the foot of, the Cuyamaca Mountains. Heavy chapparal makes it impossible to observe most faults directly. The eroded fault topography suggests that faults are pre-Quaternary, but several breaks have fresher expression—steep, vegetation-free slip faces and small landslides—so that faulting may have been reactivated locally in Quaternary time. For the most part, the faults follow Cretaceous batholithic contacts and foliation.

Geochemistry

A reconnaissance geochemical study of stream sediments was made in the Sill Hill Roadless Area in order to determine geographic variations in the abundances of major, minor, and trace elements, which might reflect local concentrations of economic minerals. Twelve geochemical sample sites are shown on figure 2 and the results of analyses for stream sediment and panned concentrate samples are given in table 1.

The results of the geochemical study of stream sediments in the Sill Hill Roadless Area do not indicate the presence of significant mineralization in the area. Most values are within the ranges expected for stream sediments that were derived from nonmineralized crystalline rocks. Most samples of unpanned stream sediments showed a relatively high background in chromium, nickel, and vanadium (150-500, 10-50, and 150-700 ppm, respectively) (table 1), probably due to the large pluton composed of the Cuyamaca Gabbro which extends into the eastern and southern parts of the study area.

Ten samples of panned concentrates have anomalous element concentrations that slightly exceed the geochemical background (table 1). The sources of the anomalous value of 1.5 ppm gold in sample 7 are probably small bodies of the granodiorite of Cuyamaca Reservoir and metasedimentary(?) rocks which occur as inclusions within the pluton composed of the Cuyamaca Gabbro upstream from the sample site. About 2 mi (3.2 km) to the north, in the Boulder Creek mining district, there is low potential for gold associated with quartz veins in host syntectonic granitic plutons. The sources of the slightly anomalous lead values of four samples are probably small contact-type deposits between metasedimentary and intrusive rocks, and (or) the radioactive disintegration of thorium in zircon, allanite, or monazite. Anomalous values in sample 2 for tungsten and nickel (100 and 70 ppm, respectively) and in sample 7 for tin (500 ppm) are probably also related to small contact-type deposits. Samples 1, 3 and 4 are anomalous in boron (2000 ppm). Pegmatite minerals, particularly tourmaline, may be the source of the anomalous boron. Samples 9, 10 and 11 are anomalous in thorium (700, 200 and 200 ppm, respectively). The most likely sources of thorium are the minerals zircon, allanite, and (or) monazite from granitic plutons and (or) silicic dikes.

Concentrations of most elements in most of the stream sediments collected in the Sill Hill Roadless Area are low, within the range of geochemical background for crystalline rocks. Exceptions are: chromium, nickel, and vanadium, probably derived from the Cuyamaca Gabbro; gold associated with quartz veins in syntectonic granitic plutons; lead, tin, tungsten and nickel probably derived from small contact-type deposits between metasedimentary inclusions and intrusive rocks; boron from pegmatite minerals; and thorium, probably derived from zircon, allanite, and (or) monazite in granitic plutons or silicic dikes. Sample sites 1 through 7 lie within the Boulder Creek mining district, which has low potential for gold. The history of mines and prospects in the study area further suggests a low potential for tungsten and nickel.

None of the stream-sediment samples have indicated any unknown deposits. Even though some of the known mineral occurrences are reflected in the samples, the intensity of prospecting over such a prolonged period in the past makes it very unlikely that any unknown deposits of significance exist.

MINING DISTRICTS AND MINERALIZATION

Mining districts

Two mining districts lie close to the study area. The Julian district is located 6 mi (9 km) to the north-northeast, near the town of Julian, and the Boulder Creek (Mineral Hill) district lies directly west of the study area (fig. 2). The Banner district was consolidated into the Julian district in 1881. During the early 1870's, \$1 - \$2 million in gold was produced from the Julian and Banner mining districts. The Stonewall mine is about 6 mi (10 km) south of the Julian district, but it is geologically similar to mines in the district, and has always been informally considered part of the Julian district. The Stonewall has not been mined since 1895; total production is estimated to have been \$2 - \$3.6 million (Everhart, 1951, p. 113). Total production for the Julian mining district is estimated at \$5 million (Weber, 1963, p. 117).

The Boulder Creek (Mineral Hill) mining district lies west of the study area (fig. 2). The chief producer in the district was the Boulder Creek (Mineral Hill) mine (fig. 2). About 2,000 ft (600 m) of drifts and cross cuts were driven, but very little gold was produced. Tucker (1925, p. 334) reported that the ore averaged \$6 - \$8 per ton (at \$20 per oz gold). The Boulder Creek mining district extends into the study area; the Central, the Penny, the Gold Crown, and the Lucky Strike prospects lie within the Sill Hill Roadless Area (fig. 2).

The Tungsten Queen prospect lies in the east-central part of the Sill Hill area (fig. 2). Workings consist of a 50-ft (15.2-m) by 20-ft (6.1-m) quarried trench which extends east from the north end of a quarried face 40 ft (12.3 m) wide, and 15 ft (4.6 m) high.

Two other workings lie near the study area, but outside of it. The Friday Nickel prospect (Stewart, 1958, p. 25) lies 4 mi (6 km) northeast of the Sill Hill area, in Cuyamaca Gabbro which also underlies part of the study area. Creasey (1946, p. 27) concluded that 5,000 tons (4,535.9 t) of resources containing 2.5 - 3.0 percent nickel and 0.5 - 1.0 percent copper, and accessory cobalt are indicated.

The Spanish Bayonet potash feldspar mine lies 1 mi (1.6 km) southwest of the Sill Hill area. Development consists mainly of an open pit which measures 100 ft (30.5 m) long, by 35 ft (10.7 m) across, by 15 to 25 ft (4.6 to 7.6 m) deep. Weber (1963, p. 82) estimates that past production was several hundred tons and very little mineable feldspar remains.

Prospects and mineralized areas

In the Boulder Creek mining district, which includes the northwest corner of the study area, trace gold occurs in quartz veins and shear zones within deformed Cretaceous granitic plutons. The plutons are irregularly elongated and show prominent foliate alignment of mineral grains (especially biotite) along a regional northwest-trending structural grain. Quartz veins and shear zones occur both together and separately, and they generally parallel the structural grain. Prominent tight isoclinal folds whose axial planes are coplanar with foliation in the granitoid plutons are common. Isoclinal folds commonly display schistose biotite-rich limbs and pegmatitic cores consisting of coarse potassium feldspar and quartz. The biotite-rich limbs may represent partially digested relict metasedimentary rocks. Quartz has escaped the fold cores in places and formed northwest-trending veins. Minute specks of free gold were observed in a quartz vein in the creek bed at the Romance No. 11 claim.

Pegmatite formation, shearing, quartz veining, and gold mineralization appear to be penecontemporaneous with formation of the syntectonic host rocks. Quartz veins were derived from a pegmatite-forming migmatic melt that formed tectonically and segregated into pockets and fissures of relatively low pressure. Although geologically interesting, the Boulder Creek deposits have been spotty and low in grade (Weber, 1963, p. 122).

Although the deposits of the Boulder Creek mining district are low in grade, syntectonic gold deposits in the Julian mining district were economicially significant. The richest gold ore in the Julian district occurred in thin layers of quartz interlaminated with schist, commonly in isoclinal folds (Donnelly, 1934, p. 353-355). Donnelly points out that deposits contained entirely or partially within metasedimentary schist have been much more productive than deposits contained in fractured, sheared, or metamorphosed granitic rock. The same gold-segregating syntectonic processes occurred in both the Julian and Boulder Creek mining districts but the scarcity of schist in the Boulder Creek district is probably the chief factor contributing to the low grade of the deposits there. Within the Sill Hill Roadless Area (fig. 2), a higher potential for gold occurrence may exist in areas underlain primarily by schistose metasedimentary rocks than in the area of known gold occurrences within the primarily granitic terrain.

The Tungsten Queen prospect lies in the east-central part of the Sill Hill area (fig. 2). Tungsten occurs as a sparse peppering of pinhead-sized scheelite ($CaWO_4$) grains in a small remnant of light-gray massive calc-silicate metasedimentary rocks. The scheelite was observed at night with a shortwave ultraviolet lamp. The metasedimentary rocks are intruded by hornblende-biotite granite along the north side of the exposed face of the scheelite-bearing zone. Joint surfaces in the metasedimentary rocks, which are coplanar with foliation, strike N. 70° E., and dip 70° S. Some epidote and garnet occur on fracture surfaces, but no good tactite development and no carbonate rocks were observed. The occurrence indicates some tungsten potential in parts of the study area that are underlain by calc-silicate metasedimentary rocks near younger intrusive rocks.

The Lower Cretaceous Cuyamaca Gabbro is the host rock for the Friday Nickel prospect northwest of the Sill Hill area, and also underlies much of the eastern and southern part of the study area. The prospect is developed in an irregular, elongated deposit that strikes N. 75° E., dips steeply northward, and pitches to the northeast (Weber, 1963, p. 198). Nickel, with accessory copper and cobalt, occurs in the sulfide minerals pentlandite, violarite, and chalcopyrite, in association with pyrrhotite (Creasey, 1946, p. 27). Creasey mapped and sampled the mine in conjunction with a strategic mineral investigation of nickel in the Julian-Cuyamaca area. He concluded that the deposit is an irregular replacement deposit that consists of nickel sulfides which entered the gabbro along northeast-striking fractures in silica-deficient hydrothermal solutions, then were ponded and precipitated along a small pendant of metasedimentary schist (Creasey, 1946, p. 26). Evidence was found for several other epigenetic nickel occurrences, but Creasey (p. 16) concluded that there is only low potential for large, low-grade (syngenetic) nickel deposits. A similar low potential for nickel can be extrapolated to parts of the Sill Hill Roadless Area which are underlain by the Cuyamaca Gabbro.

The Spanish Bayonet potash feldspar mine occurs in a very coarse grained pegmatite made up of nearly pure orthoclase with 12-in (30.5-cm) long pods of slightly rose-colored to white quartz (Everhart, 1951, p. 114). The deposit strikes N. 45° E. and dips steeply to the southeast. It occurs in the biotite-hornblende tonalite of Alpine, the equivalent of the Bonsall Tonalite. The tonalite extends into the southwestern part of the study area, where traverses disclosed a considerable amount of coarse orthoclase within the surficial float.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Mineral occurrences within and near the Sill Hill Roadless Area indicate a low potential for gold, tungsten, nickel with by-product copper, and potash feldspar. A geochemical survey of stream sediments revealed that concentrations of most major, minor, and trace elements are within the ranges expected for sediments derived from nonmineralized rocks. The overall mineral potential of the area is low, but this does not exclude the possibility of a significant mineral deposit. There are known occurrences of feldspar, gold, nickel, and tungsten in and around the study area, but none are even marginally viable under present market conditions.

In the Sill Hill Roadless Area, potential for specific mineral commodities is related to local geology (fig. 2). Areas underlain predominantly by Jurassic and Cretaceous(?) metasedimentary rocks have potential for gold deposits similar to those in the Julian mining district. Potential for tungsten deposits similar to the Tungsten Queen prospect exists in calc-silicate rocks. Local anomalous stream-sediment concentrations in lead, nickel, tungsten, and tin probably are related to similar small contact-type deposits. The part of the Boulder Creek District that lies within the study area has low gold potential.

Areas underlain by the Cuyamaca Gabbro have potential for nickel deposits. Stream sediments derived from the Cuyamaca Gabbro have relatively high geochemical backgrounds in nickel, chromium, and vanadium. There is no reason to expect that the potential for nickel deposits within the study area is any greater than the potential within the same gabbro unit in the vicinity of the Friday Nickel prospect. Creasey (1946, p. 16-17) found a very low potential for a large low-grade (syngenetic) nickel deposit, but believed that the area is worthy of consideration if a general investigation of nickel resources of the country was undertaken. Considering the limited amount of geologic terrain suitable for the occurrence of nickel within the United States, the Cuyamaca Gabbro could be an exploration target in case of a strategic need to locate domestic resources.

Areas in the southwest part of the study area underlain by the tonalite of Alpine have potential for feldspar deposits similar to the Spanish Bayonet feldspar mine located southwest of the study area.

No hydrocarbon, geothermal, or radioactive energy occurrences are known in the area, and would not be expected in the rock types present.

HAUSER ROADLESS AREA

The Hauser Roadless Area consists of 7,600 acres within the Descanso Ranger District of the Cleveland National Forest, San Diego County, California (fig. 1 and 3). The terrain is dominated by a steep south-facing slope which spans the study area and forms the north side of Hauser Canyon. Along the northern margin of the area, the slope levels out considerably between 2,800 and 3,200 ft (850 and 975 m). Relief in the area ranges from 1,600 ft (490 m) at Barrett Lake at the southwest corner to 3,837 ft (1,170 m) at Morena Butte at the east end. The area receives about 20 in (50 cm) of rain per year (Merriam, 1951, p. 119), during winter months.

GEOLOGY AND GEOCHEMISTRY PERTAINING TO MINERAL RESOURCE ASSESSMENT

Geology

The Hauser Roadless Area is underlain by five plutonic units, three of which belong to the syntectonic intrusive sequence (the Cuyamaca Gabbro, the tonalite of Japatul Valley, and the granite of Corte Madera) and two belonging to the younger sequence (the late-tectonic tonalite of Granite Mountain and post-tectonic leucotonalite, the tonalite of La Posta, the latter also designated as the La Posta Quartz Diorite of Miller, 1935). Minor prebatholithic rocks occur between plutons, chiefly metavolcanic rocks in bodies too small to portray at the map scale. Several large gouge zones were mapped in Hauser Canyon, and the existence of additional parallel zones can be inferred from indirect evidence (linear valleys, truncated contacts, vegetation bands, benches). These gouge zones mark high-angle faults that trend west to northwest and are approximately parallel to the axis of the canyon.

Geochemistry

Sixteen stream-sediment samples from the Hauser Roadless Area were analyzed for major, minor, and trace elements (fig. 3; table 1). Most of the analytical results show no significant anomalies in elemental concentrations and therefore do not suggest the presence of significant mineralization in the study area.

Most samples have higher geochemical backgrounds in chromium, scandium, zirconium, and yttrium (table 1) than are generally reported for intermediate igneous rocks. In addition, samples 10 and 13 appear to be anomalous in vanadium. The high background in chromium and scandium and the anomalous vanadium probably reflect the presence of ultramafic rocks within and adjacent to the study area. Small bodies of the Cuyamaca Gabbro crop out at several places within the Hauser Roadless Area and a large mafic to ultramafic pluton underlies Los Pinos Mountain about 3 mi (4.8 km) to the north. Ancestral southward-flowing streams deposited gabbroic detritus from the Los Pinos Mountain area onto an erosion surface developed on the large pluton composed of the tonalite of Granite Mountain, which underlies most of the northern wall of Hauser Canyon. The streams which now drain this elevated erosion surface and flow southward into Hauser Canyon are reworking the patchy remnants of this older, gabbro-dominated alluvium.

The elevated yttrium and zirconium values probably reflect the abundance of the mineral zircon in the granitic plutons and granitic pegmatites of the study area. Yttrium may also replace calcium in sphene and in allanite, both common accessory minerals in rocks of the Peninsular Ranges batholith.

The lack of significant variations in geochemical abundances in stream sediments of the Hauser Roadless Area is consistent with the absence of identified mineral resources. Both lines of evidence indicate a low potential for significant mineral resources in the study area.

MINING DISTRICTS AND MINERALIZATION

Mining activity

Based on a literature and field search for mines and prospects, there is no evidence of mining activity within the Hauser Roadless Area. Close enough to necessitate consideration, however, is the Pacific mine, a potash feldspar deposit located 0.2 mi (0.3 km) east of the study area in a zoned pegmatite dike that intruded a small pluton of granite of Corte Madera (fig. 3). Analysis by the U.S. Bureau of Mines of a 20-lb (9.1-kg) sample of perthite contained 9.20 percent K_2O, 1.92 percent Na_2O, 0.15 percent CaO, 15.8 percent Al_2O_3, 66.3 percent SiO_2, 0.14 percent Fe_2O_3, 0.01 percent MgO, 0.01 percent TiO_2, and 0.33 percent loss on ignition. From 1921 to 1943, the Pacific mine was the principal source of feldspar in California and produced 87,000 tons. The Pacific Mine has produced no gemstones and there is no lepidolite, the lithium-bearing mica which characterizes spodumene- and rare-earth-bearing pegmatites of northern San Diego County (Weber, 1963, p. 84). The zoned character of the Pacific mine is strongly reminiscent of the gem—bearing pegmatites, however, and indicates similar physical conditions of formation.

East of the study area, about 600 ft (183 m) east-southeast of Morena reservoir dam (fig. 3, no. C), is a northwest-trending quartz body 40 ft (12.2 m) long and 25 ft (7.6 m) wide (Weber, 1963, p. 216). There is no known owner and there has been no development work.

Prospects and mineralized areas

There is no known history of mining or evidence of mining claims within the Hauser Roadless Area. Two pegmatite bodies, in Corral and Salazar Canyons (fig. 3, A and B, respectively), were noted within the study area.

The Corral Canyon pegmatite, at the northern edge of the study area (fig. 3, A), is a zoned pegmatite similar to that of the Pacific mine east of the Hauser area (fig. 3, D). It is not well exposed, but appears to strike N. 70° W. and dip 50° S. and appears to be concordant with the foliation of the tonalite of Japatul Valley, the host pluton. Blocky buff-colored perthite crystals 1-2 in (2.5-5.1 cm) here appear identical to perthite at the Pacific mine. A 20 lb (9.1 kg) perthite sample contained 12.0 percent K_2O, 1.15 percent Na_2O, 0.21 percent CaO, 25.7 percent Al_2O_3, 55.6 percent SiO_2, 0.2 percent Fe_2O_3, less than 0.01 percent each MgO and TiO_2, and 0.16 percent loss on ignition.

The Salazar Canyon pegmatite, near the center of the study area (Fig. 3, B), occurs within the late- to post-tectonic tonalite of Granite Mountain. It is concordant with foliation of the pluton and strikes N. 67° E. and dips 65° N. Though not well exposed, the Salazar pegmatite is markedly different from those at the Pacific mine and Corral Canyon. It does not appear to be zoned, but consists of concordant, alternating pegmatitic and aplitic bands that consist of feldspar, quartz, and blue tourmaline and range in thickness from 0.5-2 ft (0.15-0.6 m). A 20 lb (9.1 kg) feldspar-quartz-tourmaline sample contained 5.39 percent K_2O, 2.88 percent Na_2O, 0.34 percent CaO, 13.9 percent Al_2O_3, 78.8 percent SiO_2, 0.14 percent Fe_2O_3, less than 0.01 percent MgO, 0.01 TiO_2, and 0.16 percent loss on ignition. The pegmatite body probably formed as a segregation mass (see Jahns, 1954b) within the cooling tonalite pluton.

The Pacific mine and Corral Canyon pegmatites are zoned bodies and occur in syntectonic plutons. In northern San Diego County, there are four prominent districts of gem-bearing zoned pegmatites, the Pala, Mesa Grande, Ramona, and Rincon districts (Weber, 1963, p. 86). All significant deposits within these districts occur in syntectonic plutons (see Jahns and Wright, 1952, p. 11-15, plate 2; Jahns, 1954a, p. 41; and Hanley, 1951, plate 1) or in foliated areas within massive plutons (Merriam, 1946, p. 240; and Simpson, 1965, p. 5-7). If, as appears, the zoned pegmatites are restricted to syntectonic plutons, then feldspar deposits similar to the Pacific mine should not occur in the essentially undeformed tonalite of La Posta which crops out south of the study area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

There is no evidence of potential mineral resources, either non-metallic or metallic, within the Hauser Roadless Area, with the possible exception of feldspar. There is no indication of potential geothermal, hydrocarbon, or nuclear energy resources. Geochemical analyses of 16 samples of stream sediments showed no significant variations in concentrations of major, minor, or trace elements. Local slight geochemical anomalies in a few elements reflect the abundance of particular rock types in or near the study area.

The Hauser Roadless Area has low potential for significant occurrences of potash feldspar. A field search of the area has disclosed two feldspar-bearing pegmatite occurrences. These pegmatite bodies are poorly exposed, but scattered outcrops indicate that the Corral Canyon pegmatite underlies a 500- by 100 ft area, and the Salazar Canyon pegmatite underlies a 300- by 60 ft area. Both are remote from improved highways and markets. Their potential for feldspar resources is low. Potash feldspar has been defined commercially as containing 10 percent K_2O or more, but it is currently common to find 8 percent K_2O marketed (Potter, 1981). The Corral Canyon occurrence qualifies as commercial grade potash feldspar, but low apparent tonnage, high development costs, and remoteness from markets make it uncompetitive at this time. The Salazar Canyon pegmatite has no commercial value.

CALIENTE ROADLESS AREA

The Caliente Roadless Area comprises 5,900 acres of the Palomar Ranger District of the Cleveland National Forest in northern San Diego County, California (figs. 1 and 4). The topography of the area is characterized by rugged northwest-trending mountains that are bisected by the southwest—trending canyon of intermittent Agua Caliente Creek and its tributaries. Total relief in the area is over 2,600 ft (790 m). The highest point in the area is the peak Hot Springs Mountain at 5,683 feet (1728 m) at the northwest corner of the Los Coyotes Indian Reservation (fig. 4). The lowest point, approximately 3,020 ft (918 m), is at the southern boundary of the area along Agua Caliente Creek. The mountains are covered by chapparal, cacti, and desert grasses. Conifers are abundant only in the northeast part of the study area in Lost Valley. Average rainfall in the area is approximately 16 in (41 cm) per year (Ballog and Moyle, 1980, p. 8).

GEOLOGY AND GEOCHEMISTRY PERTAINING TO MINERAL RESOURCE ASSESSMENT

Geology

The Caliente Roadless Area is underlain by prebatholithic rocks of Late Jurassic and Early Cretaceous(?) age that were intruded by the Cretaceous Peninsular Ranges batholith. The prebatholithic rocks are predominantly metasedimentary with minor calc-silicate rocks. They were metamorphosed to high grade and tightly folded so that the resulting metamorphic rocks have a steep, approximately north-trending axial-plane foliation. The rocks were first intruded by a large complex pluton ranging in composition from tonalite to granodiorite and leucogranite (the granodiorite and tonalite of Chihuahua Valley). Smaller plutons of muscovite-bearing leucogranite (the leucogranites of Warner Springs, Lost Valley, and Indian Flats) then intruded the terrane; they were the source for, and are surrounded by, broad zones of pegmatitic dikes in the older rocks. Textural relations indicate that deformation continued during intrusion of the tonalite-granodiorite pluton, but was waning by the time the muscovitic plutons were emplaced. During the latest stages of deformation, or after deformation had ended, a large homogeneous leucotonalite pluton, the tonalite of Hot Springs Mountain, was emplaced east of the study area.

The abundant granitic pegmatite dikes which cut the metasedimentary rocks and the pluton composed of the granodiorite and tonalite of Chihuahua Valley in and near the study area consist chiefly of feldspar, quartz, mica, and black tourmaline. Less commonly, pegmatite dikes also contain lepidolite (lithium-bearing mica), pink, green, and blue tourmaline, and colorless beryl. Tactite is developed locally in places where small pods of calc-silicate rocks in metasedimentary screens are in contact with granitic intrusive rocks.

Faults with various trends cut the crystalline rocks, and many small gouge zones are developed. North-trending faults offset unconformable alluvial fan deposits of probable Quaternary age. The net result of faulting appears to have been uplift of the mountain block north of Warner Springs relative to the Valle de San Jose block to the south, thus establishing the present form of the range. These faults lie between the Elsinore and San Jacinto fault zones. Less than one-half mile south of the study area, at Warner Springs, hot springs issue from six or more vents located near the southern end of a north-trending fault. The springs discharge about 150 gallons of water per minute at a maximum temperature of 139° (Waring, 1915, p. 45). Although there is no evidence of hot spring activity within the roadless area, the presence of hot spring activity 3,000 ft (920 m) south of the area suggests that hot water might circulate at depth in faults within the roadless area. The potential for geothermal resources in the Warner Springs area may be similar to that of the Imperial and Coachella Valleys 30 mi (48 km) to the northeast, a low-temperature geothermal resource province whose source of heat is assumed to be deep circulation in faults lying between the San Jacinto and San Andreas fault zones (Muffler, 1979). Therefore, the roadless area might be part of a target area if a program of geothermal exploration is initiated in this part of California in the future.

Geochemistry

Sixteen samples of stream sediments were collected from the Caliente Roadless Area for geochemical analysis (fig. 4, table 1). A panned concentrate was also analyzed for sample 10. With the possible exception of five sample sites, nos. 3-5, 7 and 8, the analytical results do not indicate the presence of significant mineralization in the study area. Geochemical anomalies in a number of elements are probably related to the abundance of certain rock types in the area.

All samples were found to be extremely high in boron and the values for samples 1, 3-5, 7, 8, and 11 are anomalous (table 1). The concentrations of fluorine in samples 2 and 6-11 are also anomalous. The combination of high boron and fluorine probably reflects the abundant tourmaline-bearing granitic pegmatite dikes which cut metasedimentary rocks, the gneiss of Harper Creek, and the granodiorite and tonalite of Chihuahua Valley. In addition, all samples contain uranium in concentrations higher than those for the rock types present; samples 1, 3, 6, and 10 are considered anomalous (table 1). The source of the anomalous uranium may be zircon and allanite from granitic pegmatite dikes. Uranium also occurs in monazite, which tends to be concentrated as a detrital mineral. The single unnamed uranium prospect in the study area occurs in a metasedimentary remnant, which suggests that the source of anomalous uranium may be metasedimentary rock detritus.

Possibly also reflecting the abundance of pegmatite dikes in the study area are unusually high concentrations of yttrium in most samples, and locally high concentrations of lanthanum, thorium, and zirconium. Samples having anomalous concentrations of yttrium are 1-3, 7, 8, 10-13, 15, and 16 (table 1). Lanthanum is anomalous in samples 7, 10, 12, and 13. The single panned concentrate, sample 10, shows anomalous scandium. Thorium is anomalous in samples 7, 10, 12, and possibly in samples 13, and 15, and zirconium in samples 3, 7, 9, 10, and 15. The association of lanthanum with thorium, zirconium and yttrium probably reflects the occurrence of zircon, allanite, and sphene in higher-than-average abundance in granitic pegmatites and (or) leucogranite plutons in the study area. Yttrium can also replace calcium in the mineral fluorite, and scandium can occur in apatite, both of which are common accessories in granitic pegmatites.

All samples contain lead in concentrations higher than is normal for the rock types present; samples 5, 6, 12, and 15 are anomalous, and the panned concentrate of sample 10 may be anomalous (table 1). Sample 12 is also anomalous in tungsten. The sources of anomalous lead and tungsten probably are local tactite zones developed in small pods of calc-silicate rocks in metasedimentary remnants and inclusions adjacent to granitic intrusive rocks. The single occurrence of scheelite (calcium tungstate) in the study area, the Bartlett and Nelson prospect (fig. 4), is located in such a zone.

The most interesting analytical results are those for the cluster of samples 3-5, 7, and 8, located in the part of Agua Caliente Creek which drains large areas underlain by metasedimentary rocks and the granodiorite and tonalite of Chihuahua Valley (fig. 4). In general, these samples are anomalous in molybdenum, silver, copper, zinc, and (or) arsenic. This suite of elements typically is associated with sulfide mineralization. Three of these samples are also anomalous in chromium and nickel, and one of them has anomalous lead (table 1). Since samples 3 through 8 are also anomalous in one or more of the elements boron, fluorine, and uranium, sulfide mineralization (pyrite?) may have been associated with pegmatite and quartz vein formation.

Sampl 10 is anomalous in gold; however, the panned concentrate for this sample shows no gold anomaly.

In summary, the generally high, partly anomalous concentrations of boron, fluorine, uranium, yttrium, lanthanum, scandium, thorium, and zirconium in stream-sediment samples from the Caliente Roadless Area probably reflect the presence of abundant tourmaline-bearing granitic pegmatite dikes and (or) the leucogranite plutons from which the dikes emanate. Generally high, and locally anomalous concentrations of lead, and anomalous tungsten in one sample (12), may reflect the presence of tactite zones in metasedimentary remnants associated with granitic intrusive rocks. Five samples are anomalous in one or more of the elements molybdenum, silver, copper, zinc and arsenic, a suite which is typically associated with sulfide mineralization. These samples are also anomalous in boron, fluorine, and uranium, which suggests that mineralization was associated with the development of pegmatite dikes and quartz veins. No prospects or mines in areas of sulfide mineralization have been reported in the study area, and no concentrations of sulfide minerals were observed during geologic mapping. Therefore, the anomalous concentrations probably represent small areas of low-grade mineralization in metasedimentary rocks cut by, and possibly hydrothermally altered by, granitic pegmatite and quartz dikes. The presence of anomalous gold in one sample does not represent a significant deposit.

MINING ACTIVITY

There are no producing mines in the Caliente Roadless Area. The Cryo-Genie mine, now inactive, has produced small quantities of tourmaline and beryl specimens and gemstones from a pegmatite dike. The Bartlett and Nelson prospect and an unnamed prospect have minor occurrences of scheelite (calcium tungstate) and uranium oxide, respectively.

The nearest operating mine is the Crest Gem (formerly known as the French Pete, Elinor deposit, Carmelita Claim, and Peter Cabot) mine, which is approximately 1/2 mi (0.8 km) northwest of the study area (fig. 4). Numerous short adits and cuts explore the thick northwest-trending southwest-dipping pegmatite. The mine reportedly produced $5,000 worth of tourmaline during the 1900's when operated by Peter Cabot, and it was the largest local producer (Weber, 1963, p. 103). Pink, green, and watermelon[1/] tourmaline were observed on the dump and in the walls of the northwestern adit. Operated part-time by Joe Laddamada, the mine currently yields several thousand pounds of quartz crystals and a few beryl crystals annually.

There are several small low-grade scheelite (calcium tungstate) deposits within tactite in the region. The nearest tungsten mine is the inactive Pawnee mine, 6.5 mi (10.5 km) northwest of the study area. The largest producer in the county, it has produced approximately 30 tons (27 t) of tungsten trioxide (WO_3) on an intermittent basis since 1917 (Weber, 1963, p. 270).

Prospects and Mineralized Areas

There are no patented claims in the study area. Three unpatented claims in the area were examined: the Cryo-Genie gemstone mine is on an active claim, the Barlett and Nelson scheelite prospect and an unnamed prospect are on inactive claims.

The Cryo-Genie mine (fig. 4) is located in two pegmatite dikes locally more than 10 ft (3 m) thick which strike northwest to northeast approximately parallel to foliation in granitic rock. One dike has scattered pockets (vugs) up to 1 ft (0.3 m) in diameter. The mine was worked in 15 pits, open cuts, and trenches up to 60 ft (18.2 m) long and 1 adit 10 ft (3 m) long. Although some tourmaline crystals are shattered and opaque, local pockets contain unshattered transparent pink, blue, and green tourmaline and colorless beryl and quartz crystals. Some crystals are suitable for mineral specimens and gemstones. According to the owner, $300 worth of gemstones and mineral specimens (principally tourmaline) was produced in 1981. Field evidence indicates that an unknown but probably small amount of similar material was produced in the past.

The Bartlett and Nelson prospect is located in a calc-silicate zone in metasedimentary rocks adjacent to granitic intrusive rocks. The zone contains tactite and local scheelite (calcium tungstate). Also occurring in the zone are pegmatite dikes up to 30 ft (9.1 m) thick which strike from north to N. 60° E. and dip almost vertically. Three of the dikes are 2 to 4 in (5. 1 to 10.1 cm) thick and are composed primarily of quartz. The prospect was worked by 11 pits and trenches ranging from 5 to 35 ft (1.5 to 10.6 m) long. Of ten tactite samples analyzed by the U.S. Bureau of Mines for tungsten trioxide (WO_3), only one contained detectable WO_3 (0.04 percent). Three samples of quartz analyzed for gold and silver contained none.

The unnamed prospect occurs in slightly radioactive metasedimentary rocks in a northwest-trending inclusion in granitic intrusive rocks. The inclusion strikes N. 12° W., dips 32° NE., is exposed along strike for 200 ft (60.1 m), and is 20 ft (6.1 m) thick. The prospect contains no workings and has

[1/] Bicolored tourmaline crystals, green on one end and pink on the other.

no record of production. The radioactivity of the metasedimentary rocks was 1.5 to 3.5 times background. Of four samples taken by the U.S. Bureau of Mines across the pendant, one had no detectable uranium oxide (U_3O_8) and three had 0.001 to 0.003 percent uranium oxide.

No significant accumulation of gold-bearing gravel occurs within the study area. Only trace amounts of placer gold were found in panned concentrates of gravel from Agua Caliente Creek, collected by U.S. Bureau of Mine personnel just south of the area.

Sand, gravel, and stone suitable for construction materials are available in the area, but similar or better quality materials are available closer to major markets.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

The results of a geochemical survey of stream sediments and the absence of producing mines in the Caliente Roadless Area both indicate low potential for mineral resources. High geochemical backgrounds of boron, fluorine, uranium, yttrium, lanthanum, thorium, and zirconium are probably related to the presence of abundant granitic pegmatite dikes in the study area. An unknown, probably small quantity of mineral specimens and gemstones has been produced from the pegmatite dike at the Cryo-Genie mine. This mine produced principally tourmaline crystals, although beryl and quartz crystals also occur. The Cryo-Genie mine has potential for future, but probably limited, production of tourmaline, beryl, quartz, and possibly other mineral specimens and gemstones. From field evidence, it is unlikely that other pegmatites in the study area have gemstone potential.

The Bartlett and Nelson prospect contains scheelite (calcium tungstate), but the potential for significant resources of tungsten is very low, and no other mineral resources are indicated. Local anomalous concentrations of lead and tungsten in stream sediments probably were derived from tactite zones similar to that at the Bartlett and Nelson prospect. Anomalous concentrations of molybdenum, silver, copper, zinc, and arsenic in five samples probably represent low-grade sulfide mineralization in metasedimentary host rocks, perhaps small pyrite deposits associated with pegmatite and quartz dikes. An unnamed prospect in the study area contains minor uranium; no uranium resources are indicated.

Alluvial sand and gravel deposits in the study area contain only traces of placer gold. Sand and gravel are not considered to be important resources because transportation costs are a major part of total costs for these high-bulk, low-unit-value commodities.

Although there are several hot springs south of the area, there is no evidence of hot spring activity within the Caliente Roadless Area and the potential for geothermal resources is probably low. There is no evidence of potential hydrocarbon energy resources.

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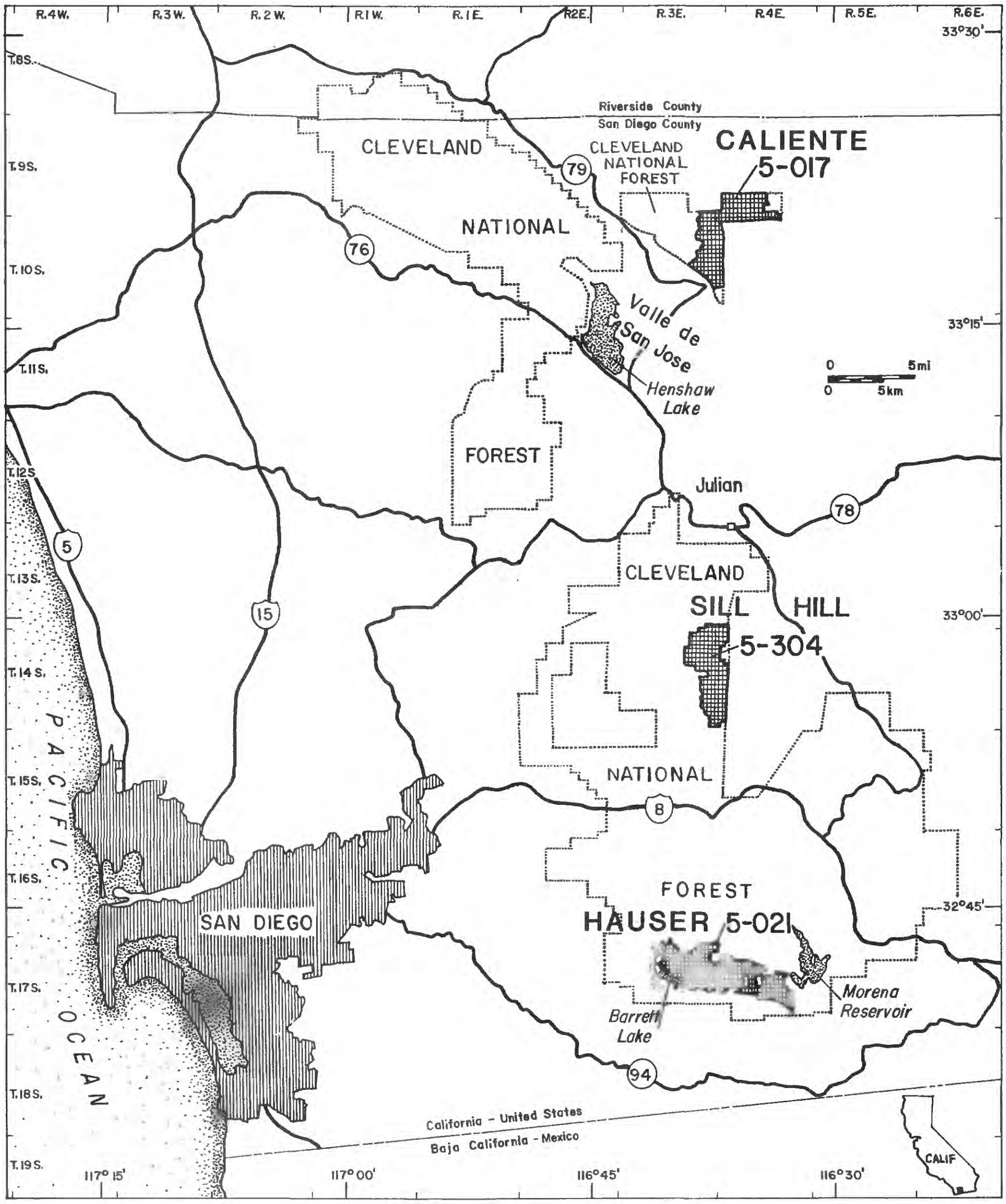

Figure 1. Index map for Sill Hill, Hauser, and Caliente Roadless Areas, San Diego County, California

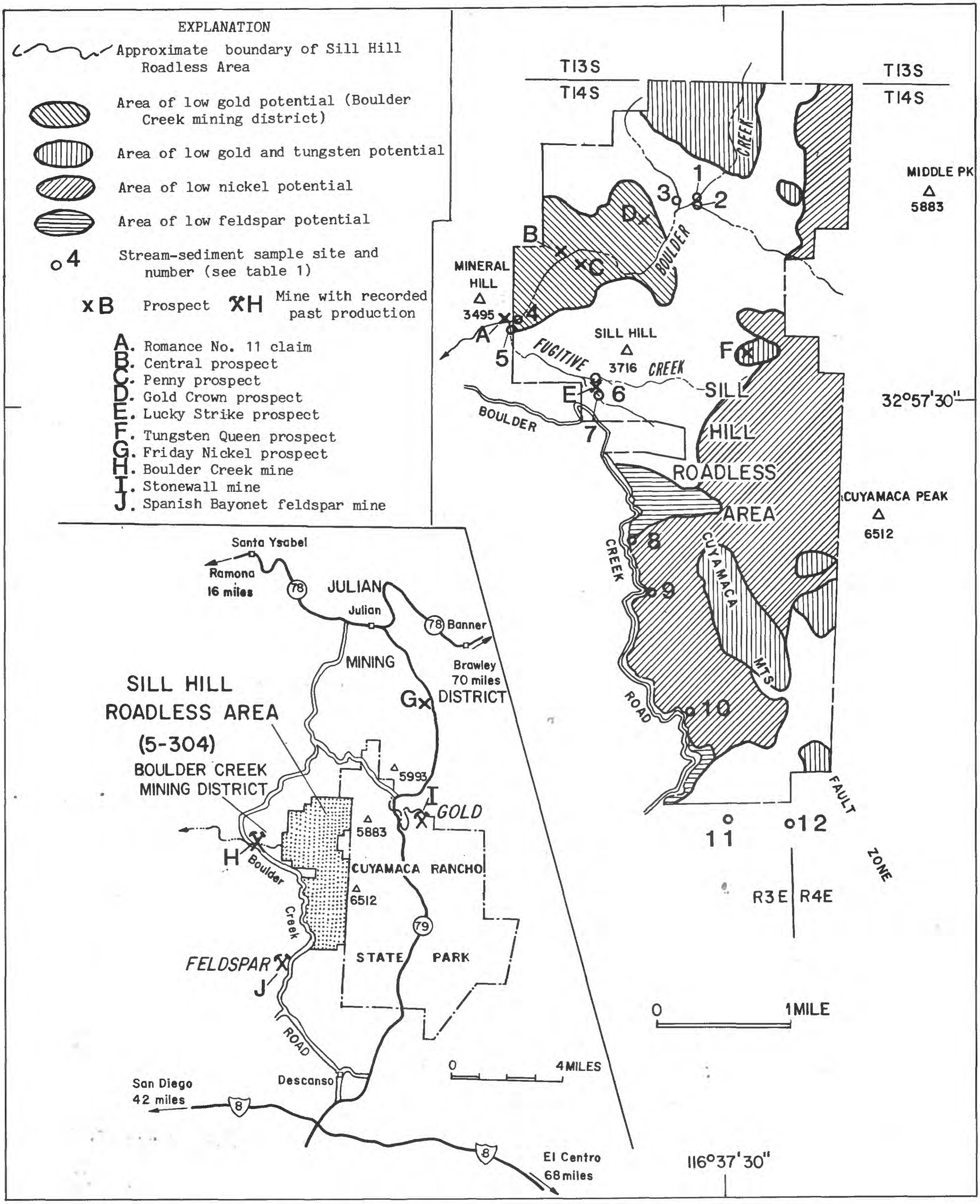

Figure 2. Mineral Resource Potential Map for Sill Hill Roadless Area

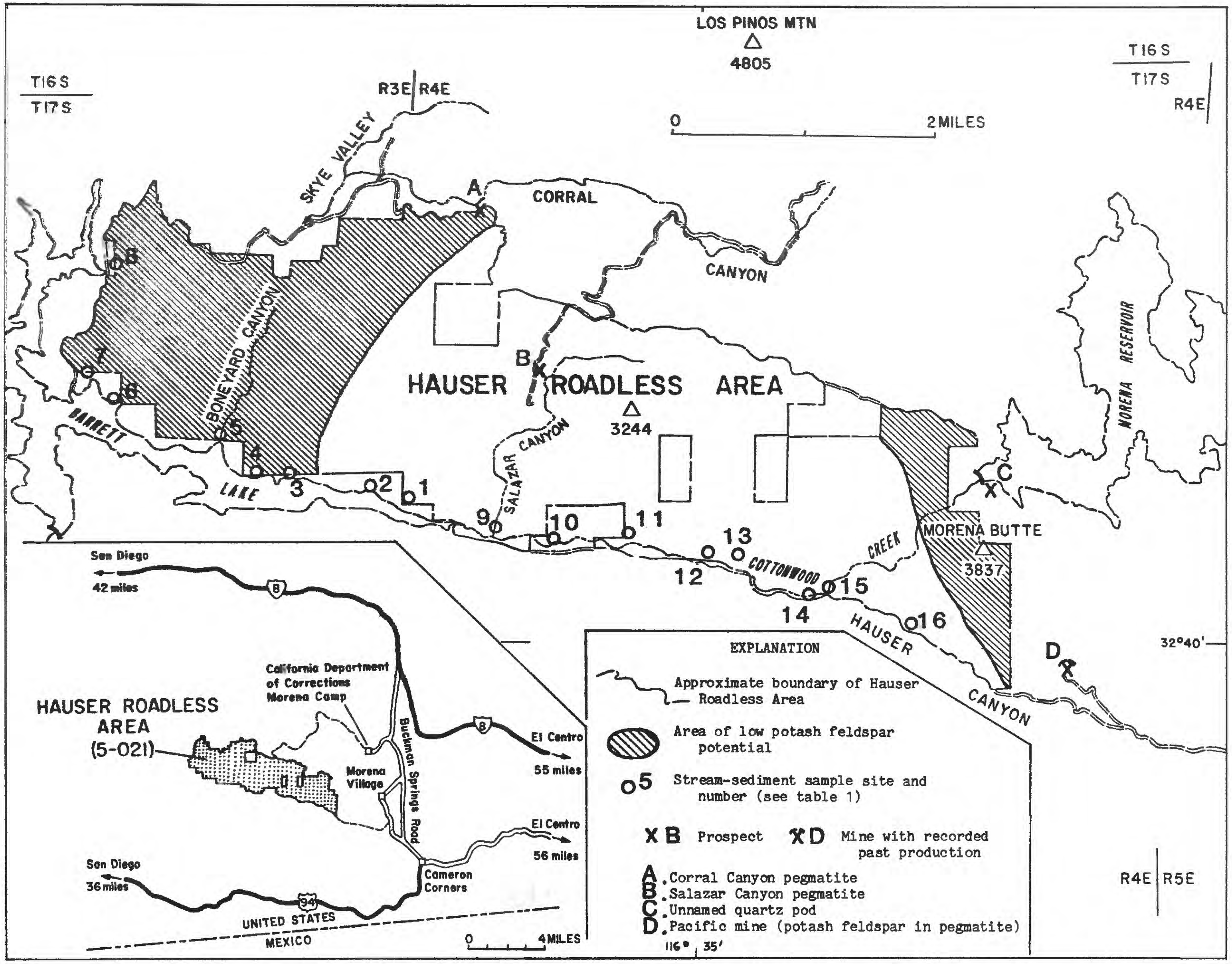

Figure 3. Mineral Resource Potential Map for Hauser Roadless Area

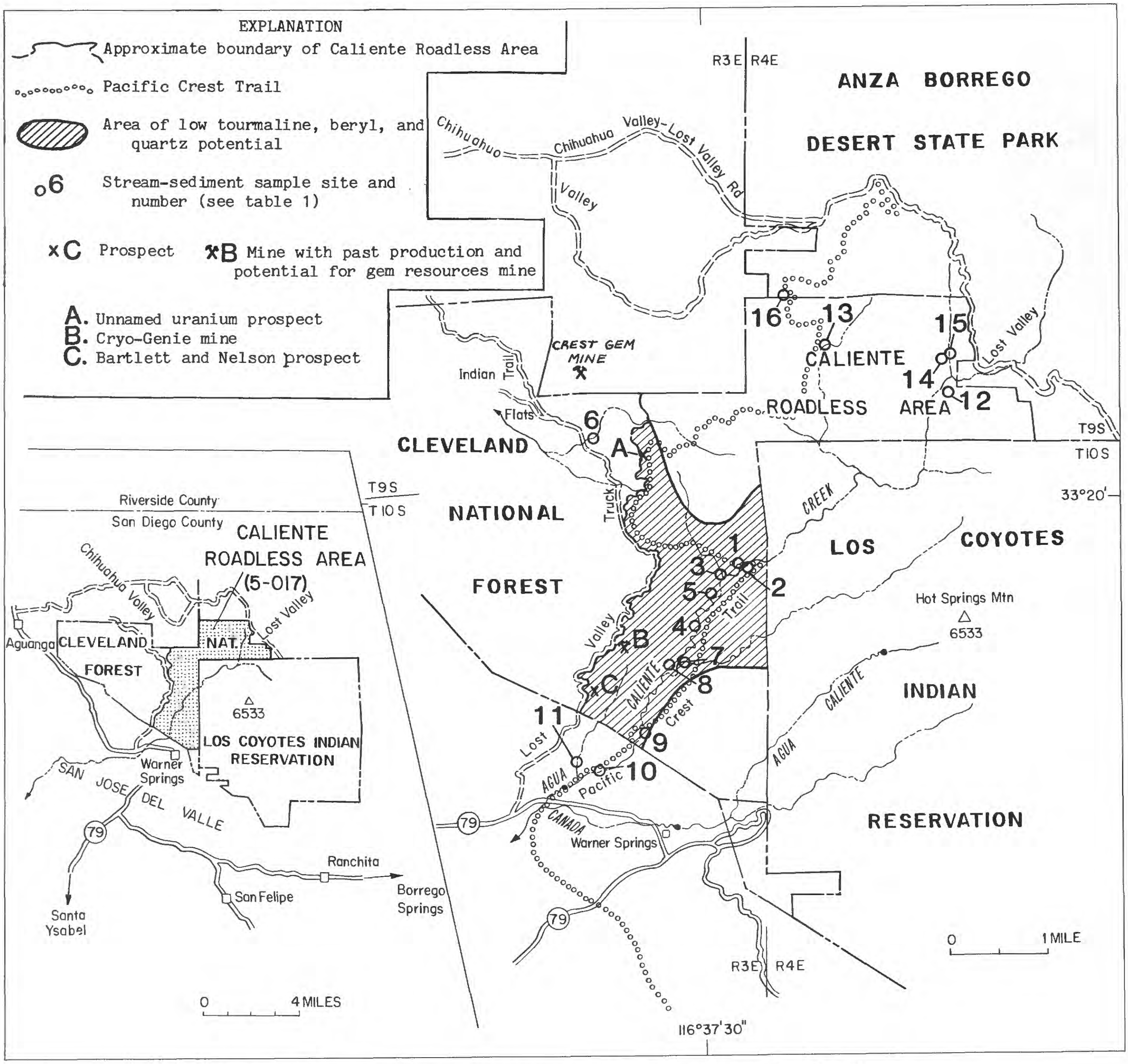

Figure 4. Mineral Resource Potential Map for Caliente Roadless Area

Table 1.--Analyses of samples from the Sill Hill, Hauser, and Caliente Roadless Areas, California

[All analyses performed by U.S. Geological Survey. For samples analyzed by semiquantitative emission spectrographic method, results are reported as six steps (1.5, 2, 3, 5, 7, 10, in order of magnitude) and numbers of this series multiplied by powers of 10; these steps represent the approximate geometric midpoints of concentration ranges whose boundaries are as follows: 1.2-1.8, 1.8-2.6, 2.6-3.8, 3.8-5.6, 5.6-8.3, 8.3-12. The analytical results can be expected to fall within one reporting interval of the mean 83 percent of the time and within two reporting intervals of the mean 96 percent of the time. Semiquantitative analyses for As, Au, Bi, Cd, and Sb revealed no significant values, and are not included. Analyst, D. E. Dutra.

Quantitative chemical analyses for selected elements were performed by the following methods: Au, Zn, atomic absorption; As, Gutzeit method (wet chemical); W, colorimetric; F, specific ion; and U, fluorimetric. Analyst, B. F. Arbogast.
Symbols used are G= Greater than value shown; I= Interference; N= Not detected at limit of determination, or at value shown in parentheses; L= Detected but below limit of determination, or below value shown in parentheses; *= anomalous value, one that exceeds geochemical background of analyzed samples by a significant amount as empirically determined . All values reported in parts per million unless otherwise noted. SH= Sill Hill; H= Hauser; C= Caliente.]

Sample			Semiquantitative emission spectrographic analyses																									Chemical analyses					
Number	Location		Percent				Parts per million																					Parts per million					
	Lat. (N.)	Long. (W.)	Fe	Mg	Ca	Ti	Mn	Ag	B	Ba	Be	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sc	Sn	Sr	Th	V	W	Y	Zn	Zr	Au	As	Zn	W	F	U
Stream sediments 1/																																		
Lower detection limit			(0.05)	(0.02)	(0.05)	(0.002)	(10)	(0.5)	(10)	(20)	(1)	(5)	(10)	(5)	(20)	(5)	(20)	(5)	(10)	(5)	(10)	(100)	(100)	(10)	(50)	(10)	(200)	(10)						
SH- 1	32°58' 47"	116°37' 41"	5	1	1	G1	1000	N	50	200	N	20	150	20	20	N	N	15	15	30	N	150	N	200	N	30	N	150	N(0.05)	L(10)	40			
2	32°58' 43"	116°37' 39"	3	1	1	1	1000	N	50	300	1	15	300	15	L	N	N	15	20	20	N	200	N	150	N	30	N	100	N(0.05)	L(10)	50			
3	32°58' 45"	116°37' 49"	5	1	1.5	G1	1500	N	100	300	L	15	50	15	20	N	N	10	15	20	N	200	N	150	N	50	N	200	N(0.05)	N(10)	35			
4	32°58' 01"	116°39' 01"	5	1	1	G1	1500	N	100	200	1	15	300	15	20	N	N	10	10	20	N	150	N	150	N	30	N	200	N(0.05)	N(10)	35			
5	32°57' 58"	116°39' 04"	5	2	2	G1	1500	N	30	200	1	20	500	10	20	N	N	15	20	30	N	150	N	150	N	50	N	500	N(0.05)	N(10)	25			
6	32°57' 39"	116°38' 28"	5	2	1.5	G1	2000	N	50	200	1	20	300	15	20	N	N	10	20	50	N	200	N	150	N	50	N	1000	N(0.05)	N(10)	40			
7	32°57' 34"	116°38' 26"	5	2	2	G1	1500	N	30	150	L	30	500	20	20	N	N	20	10	50	N	150	N	150	N	30	N	500	N(0.05)	N(10)	30			
8	32°56' 38"	116°38' 10"	10	2	3	G1	1500	N	20	150	L	50	300	50	20	N	N	20	L	50	N	200	N	500	N	20	N	200	N(0.05)	N(10)	20			
9	32°56' 28"	116°38' 02"	3	2	2	1	1500	N	20	100	L	50	500	50	N	N	N	50	L	50	N	150	N	200	N	15	N	500	N(0.05)	N(10)	20			
10	32°55' 44"	116°37' 45"	10	2	2	G1	2000	N	30	100	N	50	500	70	N	N	N	50	10	50	N	150	N	700	N	20	N	150	N(0.05)	N(10)	20			
11	32°54' 53"	116°37' 26"	5	2	2	1	1500	N	30	150	L	50	500	50	L	N	N	20	L	50	N	150	N	300	N	30	N	200	N(0.05)	N(10)	30			
12	32°54' 52"	116°36' 59"	5	2	2	G1	1500	N	50	200	1	30	300	50	L	N	N	20	30	50	N	150	N	150	N	50	N	300	N(0.05)	L(10)	40			
H- 1	32°40' 57"	116°37' 17"	2	1.5	2	.2	1000	N	20	200	L	15	30	20	N	N	N	10	20	30	N	200	N	150	N	30	N	100						
2	32°41' 05"	116°37' 40"	5	2	2	.7	1000	N	30	200	5	30	200	10	L	N	N	20	10	70	N	150	N	200	N	70	N	G1000						
3	32°41' 09"	116°38' 16"	3	2	2	.5	1000	N	30	150	1	20	70	20	20	N	N	15	20	50	N	150	N	150	N	50	N	700						
4	32°41' 10"	116°38' 33"	5	1.5	2	.7	1500	N	50	150	3	30	100	15	20	N	N	10	15	70	N	150	N	200	N	100	N	G1000						
5	32°41' 24"	116°38' 51"	5	1	2	.7	1000	N	20	150	2	30	100	15	30	N	N	10	15	70	N	150	N	200	N	100	N	1000						
6	32°41' 38"	116°39' 44"	5	1	2	1	1500	N	20	150	L	15	70	10	L	N	N	7	15	50	N	200	N	200	N	50	N	500						
7	32°41' 49"	116°39' 54"	3	1.5	2	1	1000	N	15	200	L	20	70	15	L	N	N	7	20	30	N	150	N	150	N	50	N	500						
8	32°42' 33"	116°39' 50"	5	1	2	1	1000	N	30	150	2	20	100	15	20	N	N	10	10	30	N	200	N	200	N	100	N	700						
9	32°40' 47"	116°36' 38"	5	1	3	.7	1500	N	70	150	5	20	200	15	20	N	N	7	10	70	N	200	N	200	N	70	N	G1000						
10	32°40' 43"	116°36' 11"	7	1	2	G1	2000	N	50	150	5	20	300	20	20	N	N	10	L	70	N	150	N	500*	N	50	N	G1000						
11	32°40' 44"	116°35' 36"	7	1.5	2	.7	1500	N	50	150	3	20	200	20	L	N	N	10	10	70	N	200	N	200	N	70	N	G1000						
12	32°40' 37"	116°34' 56"	10	1.5	3	1	1500	N	30	150	3	20	200	20	20	N	N	10	10	70	N	200	N	200	N	70	N	G1000						
13	32°40' 38"	116°34' 42"	10	1	2	1	2000	N	50	100	5	20	300	20	20	N	N	10	L	100	N	150	N	500*	N	50	N	G1000						
14	32°40' 21"	116°34' 08"	5	1.5	2	.5	1000	N	30	200	2	20	100	15	L	N	N	10	10	70	N	200	N	150	N	50	N	G1000						
15	32°40' 23"	116°33' 59"	3	1	2	.7	1500	N	50	200	1.5	15	70	10	30	N	N	L	15	50	N	200	N	100	N	50	N	700						
16	32°40' 09"	116°33' 21"	5	1	5	1	1500	N	30	200	3	20	100	10	70	N	N	10	20	50	N	200	N	200	N	150	N	G1000						
C- 1	33°19' 25"	116°37' 08"	5	1	2	G1	1500	N	200*	1000	1.5	15	50	10	50	N	L	10	30	20	N	200	N	150	N	100*	N	500	N(0.05)	L(10)		I10	L(100)	12.7*
2	33°19' 24"	116°37' 13"	2	.7	1.5	.5	700	N	70	1000	2	10	30	10	100	N	N	10	50	10	N	200	N	100	N	150*	N	150	N(0.05)	L(10)		I 2	100*	6.7
3	33°19' 19"	116°37' 20"	3	1	2	.7	1000	N	200*	1500	3	15	70	30	70	L*	N	20	50	15	N	300	N	150	N	100*	N	1000*	N(0.05)	L(10)		I10	L(100)	16.6*
4	33°18' 53"	116°37' 36"	3	1	1.5	1	1000	L*	1000*	1000	2	15	100*	150*	100	10*	L	70*	50	15	N	300	N	200	N	50	200*	200	N(0.05)	L(10)		I 5	L(100)	5.5
5	33°19' 09"	116°37' 25"	2	1	1.5	.7	700	N	700*	1000	3	10	100*	50*	70	L*	N	50*	100*	15	L	300	N	150	N	30	200*	200	N(0.05)	10*		I 5	L(100)	7.2
6	33°20' 34"	116°38' 40"	2	.7	5	.5	1000	N	100	1000	3	5	30	10	100	N	N	5	100*	15	15	500	N	100	N	50	N	700	N(0.05)	N(10)		I 2	400*	15.0*
7	33°18' 32"	116°37' 43"	2	1	2	1	700	N	700*	2000	3	10	70	50*	500*	5*	L	20	30	15	N	500	100*	100	N	500*	N	1000*	N(0.05)	L(10)		I 5	500*	2.9
8	33°18' 31"	116°37' 53"	3	1.5	1.5	1	1000	N	1000*	1500	2	15	100*	70*	200	L*	L	50*	50	20	N	300	N	150	N	100*	L*	200	N(0.05)	L(10)		I 5	1800*	3.9
9	33°17' 53"	116°38' 06"	3	1.5	5	.7	700	N	100	2000	2	10	100*	20	100	N	N	15	50	20	N	500	N	100	N	50	N	G1000*	N(0.05)	N(10)		I 2	300*	1.2
10	33°17' 33"	116°38' 39"	2	.7	2	1	2000	N	150	2000	3	10	30	15	700*	N	N	7	50	15	N	200	100*	70	N	200*	N	G1000*	.15*	N(10)		I 5	200*	11.0*
11	33°17' 40"	116°38' 52"	3	2	2	1	1500	N	500*	2000	2	15	70	70*	200	N	N	20	50	20	N	300	N	150	N	100*	N	500	N(0.05)	L(10)		L(2)	200*	5.2
12	33°20' 56"	116°34' 53"	2	1	2	.7	2000	N	50	1000	3	10	30	20	1000*	N	N	L	70*	15	L	300	150*	70	N	150*	N	500	N(0.1)	N(10)		2*	L(100)	9.5
13	33°21' 21"	116°36' 11"	2	1	2	.7	1500	N	50	1000	3	7	20	15	500*	N	N	L	50	15	L	500	L	70	N	300*	N	200	N(0.5)	N(10)		L(2)	L(100)	4.9
14	33°21' 13"	116°34' 55"	1	.3	1.5	.1	500	N	70	1500	3	L	10	L	100	N	N	L	50	7	N	200	N	50	N	20	N	100	N(0.1)	N(10)		I 2	L(100)	5.5
15	33°21' 14"	116°34' 52"	2	.5	1.5	1	2000	N	20	1000	5	5	20	10	200	N	L	L	70*	10	N	200	L	50	N	200*	N	1000*	N(0.05)	L(10)		I 2	L(100)	6.4
16	33°21' 49"	116°36' 38"	2	2	5	.7	1000	N	30	1500	2	15	70	20	50	N	N	7	50	30	15	200	N	200	N	100*	N	700	N(0.05)	N(10)		I 2	L(100)	7.6
Panned concentrates 2/																																		
Lower detection limit			(.1)	(.05)	(.1)	(.005)	(20)	(1)	(20)	(50)	(2)	(10)	(20)	(10)	(50)	(10)	(50)	(10)	(20)	(10)	(20)	(200)	(200)	(20)	(100)	(20)	(500)	(20)						
SH- 1			7	3	5	2	1500	N	2000*	100	10	50	500	10	200	N	L	10	N	100	L	L	L	500	N	500	N	G2000	N(0.25)	L(10)				
2			5	2	3	1.5	1500	N	700	150	15	50	1000	L	150	N	N	70*	N	100	50	L	L	200	100*	500	N	G2000	N(0.5)	10				
3			3	1.5	2	2	1000	N	2000*	150	20	15	50	10	300	N	N	L	L	70	N	200	N	200	N	300	N	G2000	N(0.25)	N(10)				
4			3	2	5	2	1500	N	2000*	100	15	20	500	10	150	N	L	L	L	70	30	N	N	200	N	700	N	G2000	N(0.2)	N(10)				
5			5	5	5	1.5	2000	N	1000	100	20	50	700	10	50	N	N	20	20	100	L	N	N	300	N	500	N	G2000	N(0.2)	N(10)				
6			3	3	5	1.5	1500	N	500	100	15	15	500	L	100	N	N	L	100*	50	N	L	N	150	N	300	N	G2000	N(0.5)	N(10)				
7			3	5	7	2	1500	N	1000	100	30	30	700	20	70	N	N	10	300*	100	500*	L	N	200	N	500	N	G2000	1.5*	N(10)				
8			5	3	5	1.5	1500	N	200	100	7	30	200	10	L	N	N	20	L	50	N	300	N	200	N	100	N	G2000	N(0.25)	N(10)				
9			5	5	7	1	1000	N	100	100	10	30	200	15	1500	N	N	20	70*	50	N	300	700*	200	L	200	N	G2000	N(0.25)	L(10)				
10			5	5	10	1	1500	N	200	100	15	50	500	15	200	N	N	30	100*	70	N	200	200*	200	N	200	N	G2000	N(0.25)	L(10)				
11			5	5	7	2	1000	N	500	100	20	50	700	15	200	N	N	30	N	70	20	200	200*	200	L	300	N	G2000	N(0.25)	L(10)				
12			5	5	5	2	1500	N	200	100	10	30	500	10	100	N	L	10	L	70	30	N	N	200	N	300	N	G2000	N(0.25)	N(10)				
C- 10			1	.5	5	G2	500	N	1500	100	20	20	150	20	G2000	N	50	10	70	G200*	50	N	1500	150	100	1000	N	G2000	N(0.5)	L(10)				

1/ Stream-sediment samples are composites collected by combining three to six subsamples from several locations within the stream channel. The composite sample was then passed through a 2-mm sieve, and material coarser than 2 mm was discarded. For selected samples, a split of the composite sample was panned to yield the heavy mineral concentrate. The bulk sand samples and panned concentrates were routinely sieved to -80 mesh fractions before grinding.

2/ A panned-concentrate sample is the heavy mineral concentrate of a bulk stream-sediment sample. After being sieved to -80 mesh, magnetite was removed by hand magnet, and the concentrate was immersed in bromoform (S.G. 2.89) to remove remaining low-density minerals. The concentrate was then separated into paramagnetic and nonmagnetic fractions with the Franz magnetic separator. The nonmagnetic panned concentrate was then pulverized before analysis.