MINERAL RESOURCE POTENTIAL OF THE BLACK BUTTE AND ELK CREEK ROADLESS AREAS, MENDOCINO, LAKE, AND GLENN COUNTIES, CALIFORNIA

SUMMARY REPORT

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STUDIES RELATED TO WILDERNESS

Under provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and related acts, the U.S. Geological Survey and the U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System, and some of them are presently being studied. The act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. The act directs that the results of such surveys are to be made available to the public and be submitted to the President and the Congress. This report discusses the results of a mineral potential survey of the Black Butte (05269) and Elk Creek (05140) Roadless Areas, Mendocino National Forest, Mendocino, Lake, and Glenn Counties, California. Black Butte and Elk Creek Roadless Areas were classified as further planning areas during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January 1979.

SUMMARY

Geologic, geochemical, and geophysical investigations indicate that the potential for energy-related or metallic mineral resources in the Black Butte and Elk Creek Roadless Areas is low.

No mines or prospects are present in the study areas. No oil or gas seeps or coal seams were detected within the study areas. The low porosity and permeability of sandstones of the Franciscan assemblage that occur in the areas indicate a very low potential for oil or gas. The geothermal energy potential of the areas is also low.

Manganese appears to be the only commodity of any resource significance in these areas. Copper, barium, cobalt, and gold appear to be associated with manganese-bearing chert and volcanic rock. The resource potential for manganese is considered to be low due to the meager concentration of metals present and the small size and discontinuous nature of the mineralized areas. Some deposits of moderate potential may exist outside of the study areas, where limited manganese mining has occurred.

Chromium, nickel, gold, and platinum-group elements are found in association with chromite in small ultramafic bodies. The resource potential for these elements is low because of a lack of appreciable amounts or concentrations of chromite segregations within the ultramafic rocks.

Minor copper mineralization is associated with altered basic igneous rocks. A very low potential for copper resources is indicated due to the small size of the igneous bodies and low concentration of copper relative to background level.

Bedrock samples of sandstone, shale, and tuff show trace amounts of gold and silver. No significant resource is indicated due to the low concentrations of these metals and spotty distribution of gold- or silver-bearing samples.

Small alluvial deposits are present in Elk Creek and Black Butte River, but due to their small size and remote location they are not considered to be a significant sand and gravel resource.

INTRODUCTION

The Black Butte and Elk Creek Roadless Areas each comprise approximately 40 mi^2 in Mendocino National Forest, in Mendocino, Glenn, and Lake Counties, Calif. (fig. 1). The areas are nearly contiguous along Forest Service Route M1 and have similar geology and mineral resource potential. An area larger than that defined by the roadless area boundaries was mapped to better understand the geology and to sample areas of known mineralization.

The study areas are located in the eastern part of the northern California Coast Ranges and are characterized by northwest-trending ridges separated by steep-sided valleys. Elevations range from 1,500 ft to 6,600 ft, commonly with gradients of 1,000 ft per mi. The steep slopes are covered by brush, grass, oak, and conifer forests. Access to the areas is either by State Highway 261 from Covelo or by county road from Potter Valley, which is approximately 16 mi southwest of Lake Pillsbury. Forest Service Route M1 trends roughly north and connects the two roads. Side roads used for logging and jeep trails provide access to the study areas.

Present and previous studies

The U.S. Geological Survey conducted an areal geologic study of the roadless areas during the summers of 1980 and 1981, consisting of geologic mapping and sampling of stream sediment and bedrock for geochemical analysis. The U.S. Bureau of Mines conducted a mineral resource appraisal during July 1981; personnel searched courthouse claim records, reviewed U.S. Bureau of Land Management and U.S. Forest Service files and records, and evaluated localities with possible mineral resources.

Unpublished reports by the California Department of Water Resources (1966, 1968, 1969) aided the preparation of the geologic map and provided aeromagnetic and gravity surveys covering most of the study area. Exploration holes drilled during the CDWR studies were later used for heat-flow measurements (Lachenbruch and Sass, 1980). Student theses (Lehman, 1974; Jordan, 1975; Etter, 1979) describe regional geology for the study areas and document intrusive rocks in the Elk Creek Roadless Area (Layman, 1977). Irwin (1960) described the geologic setting of the area and summarized the mineral resources. Publications by the California Division of Mines and Geology describe mineral deposits and past mineral production for the region (Eric, 1948; Trask and others, 1943; Trask, 1950).

GEOLOGY, GEOCHEMISTRY, AND GEOPHYSICS PERTAINING TO MINERAL RESOURCE ASSESSMENT

Geology

The study areas are underlain by rocks of the Franciscan assemblage, which range in age from Late Jurassic to Late Cretaceous, and by ultramafic rocks and serpentinite probably belonging to the Upper Jurassic Coast Range ophiolite (fig. 2). The Franciscan assemblage is subdivided into four tectonostratigraphic units based on differences in lithology, degree of metamorphism, and style of deformation. Structurally lowest and least metamorphosed of these units is a melange, assigned to the Central belt of the Franciscan assemblage. The melange is characterized by penetratively sheared argillite and thin-bedded sandstone. Included as blocks or "knockers" within the argillite are other Franciscan lithologies. Some of these incorporated lithologies are of significance for their base metal content, including manganiferous bedded chert and mafic volcanic rocks (greenstone). Fossiliferous blocks of sandstone, conglomerate, chert, and limestone within the melange contain mollusks and radiolaria of Late Jurassic age (Tithonian) and foraminifers of Late Cretaceous age (Cenomanian) (Berry, 1981; Blake and Jones, 1974). The deduced time of mixing of the melange component is Late Cretaceous or younger.

In the southwestern part of the map area the melange is overlain by the metasandstone, argillite, and chert of Sanhedrin Mountain along a low-angle fault. This unit is deformed and metamorphosed to textural zone 2 of Blake and others (1967). The unit contains abundant thick lenses of interbedded chert and sparse lenses of greenstone. Many of the chert lenses are manganiferous and have been mined outside the roadless area for that commodity in the past. No fossils were found in this unit, although it has been assigned to the middle Cretaceous by Jordan (1975) and Etter (1979). It is here considered to be of Jurassic and (or) Cretaceous age.

The metasandstone and argillite of Hull Mountain is interpreted to be a tectonic slab incorporated into the melange of the Central belt of the Franciscan assemblage. The Hull Mountain unit structurally bounds the Sanhedrin Mountain unit along a northwest-trending high-angle fault zone. The Hull Mountain unit is deformed and reconstituted to textural zones 1 and 2 of Blake and others (1967), and it contains minor lenses and blocks of greenstone and manganiferous radiolarian chert. The metasandstone is intruded by gabbroic dikes and sills in the vicinity of Monkey Rock, but no apparent mineralization is associated with these intrusives. The Hull Mountain unit is dated by interbedded radiolarian chert exposed in Elk Creek, which is assigned a Late Cretaceous (Aptian or Albian) age (C. D. Blome, written commun., 1982), and by a mollusk locality near Hull Mountain that contains Late Cretaceous (Cenomanian) fossils (Blake and Jones, 1974). Rocks near Mendocino Pass and in the area north of Bald Mountain are correlated with the Hull Mountain unit and are part of the much larger Yolla Bolly terrane of Blake and others (1981).

The structurally highest unit of the Franciscan assemblage is the metasandstone, argillite, and metavolcanic rocks of Black Butte and Bald Mountain. These rocks structurally overlie both the melange unit and the Hull Mountain unit along a low-angle thrust fault. This structurally highest unit is composed largely of metasandstone and argillite, extensively reconstituted to schist of textural zone 2 to 3 of Blake and others (1967). Abundant metamorphosed tuff and basalt are intercalated with the schist in the Black Butte area. In addition to the volcanic rocks, small amounts of metamorphosed mafic igneous rocks are present in the Bald Mountain area. The unit is here considered to be of Jurassic and(or) Cretaceous age.

The Sanhedrin Mountain, Hull Mountain, and Black Butte-Bald Mountain units all are metamorphosed to pumpellyite or blueschist grade. Generally, in this area rocks in textural zone 2 to 3 are of highest blueschist grade. Numerous blocks in the melange unit are of high blueschist grade, but these are tectonically mixed with rocks of much lower metamorphic grade.

At the Blue Banks a large exposure of serpentinite locally underlies the melange unit. Serpentinite bodies also occur in the Devils Rock Garden-Barley Lake area, along Elk Creek, in the Bennett Valley-Eden Valley area, and on Brushy Mountain. These serpentinite bodies are alpine-type ultramafic rocks composed of tectonized dunite and peridotite in a sheared matrix of serpentine minerals. Ratios of platinum-group metals (palladium, platinum, and rhodium) in a chromitite sample collected from the Devils Rock Garden serpentinite indicate ophiolitic parentage for the serpentinite (Page and others, 1982). This and other field evidence from adjoining areas suggest that the serpentinite was derived from the lower portion of the Coast Range ophiolite.

Landslide deposits cover significant portions of the study areas but are not shown on the simplified geologic map. Undoubtedly, they would affect any development of the area, but they are not relevant in assessing the mineral potential.

Geochemistry

The ferrous-, base-, and precious-metal resource potential of the study areas was evaluated using conventional geochemical sampling and analytical techniques. Stream-sediment samples were collected along the major drainages and tributaries of both areas and concentrated by panning. Most sediment samples are composed of lithic detritus with very few monomineralic heavy mineral grains. In addition to stream-sediment samples, representative bedrock samples were analyzed from each map unit and from areas of mineralized rocks. All samples were split and duplicate samples were submitted for analysis.

The samples were analyzed by semiquantitative six-step spectrographic and atomic-absorption techniques (Grimes and Marranzino, 1968). The gold-film method was used for mercury determinations. Fire-assay and spectrographic techniques were used for analysis of platinum-group elements. The analytical data were computer processed using programs for the U.S. Geological Survey's STATPAC system (Van Trump and Miesch, 1977) to determine background and anomalous quantities of metallic elements. Results from the analysis of stream-sediment samples were computer processed separately from the bedrock and mineralized rock samples. A threshold value (lowest value considered anomalous) was determined for each element by either of two methods: (1) adding two standard deviations to the calculated background value for that sample population, or (2) a graphical solution formulated by LePeltier (1969) using cumulative frequency curves. When the population for a given element approximates a log-normal distribution, the threshold values determined by the two methods are the same. The method of LePeltier is sensitive to the presence of complex statistical populations in which case the inflection point between the normal population and the anomalous population is chosen as the threshold value. Any detected value for gold or platinum is considered anomalous. Table 1 lists the sample localities with anomalous concentrations of metallic elements.

In many sample localities, anomalous values were obtained for a metal in only one replicate sample. Samples were considered anomalous only if both splits exceeded the threshold value for a particular metal. Analysis for platinum-group elements was performed only on bedrock samples from ultramafic bodies and pan-concentrated stream-sediment samples. No detectable amounts of platinum-group elements were found in the stream-sediment samples. Because of their low natural concentrations, gold and platinum are considered significant where detected in only one sample split, but where this occurs, these localities are queried.

Additional bedrock and pan-concentate samples were taken by J. M. Spear, U.S. Bureau of Mines, but were not computer processed with the samples previously discussed. The bedrock samples were fire assayed for gold and silver; some samples were analyzed by semiquantitative spectrographic methods for 42 elements[1] to detect the presence of unsuspected minerals. Heavy minerals in the pan-concentrate samples were initially concentrated by hand panning, then further concentrated on a laboratory-sized Wilfley table. All lode and pan-concentrate samples collected by the U.S. Bureau of Mines were checked for radioactivity and fluorescence.

Geophysics

Aeromagnetic surveys are available for the study areas except for the Mendenhall Creek-Hull Mountain area (California Department of Water Resources 1966, 1969; California Division of Mines and Geology 1978). A single Bouger gravity profile has been made traversing east-west across the southern part of the Black Butte Roadless Area (California Department of Water Resources, 1966). The positive magnetic anomalies can be related to surface exposures of serpentinite. Geophysical modeling of two anomalies, one at the Blue Banks and the other at Brushy Mountain, are presented in an office report of the California Department of Water Resources (1966). The aeromagnetic pattern over the Blue Banks serpentinite indicates that it has substantial vertical extent. A pronounced steep-sided positive gravity anomaly also present over the Blue Banks serpentinite is interpreted to suggest vertical faulting. A shear zone west of Blue Banks is interpreted to be a fault zone along which the serpentinite was down faulted and sheared into the melange. The aeromagnetic and gravity anomaly at Brushy Mountain is outside both study areas, but it may be related to a surface exposure of serpentinite that is modeled to have a considerable vertical extent. Heat-flow measurements are available from three exploration holes near and within the study areas. The heat-flow values range within the normal distribution of values for the region (Lachenbruch and Sass, 1980).

MINING DISTRICTS AND MINERALIZATION

Mendocino County and U.S. Bureau of Land Management records indicate that no mining claims have been located in the study areas. Claims were located for manganese to the west and south of the Elk Creek Roadless Area (see fig. 2) from 1917 to the 1940's, but there is no evidence of current mining activity at these claims or in either roadless area. Although there is no mining activity in the study areas, the geologic setting indicates at least low potential for the discovery of manganese and chromium resources.

Sediment samples from several localities contain slightly high metallic anomalies. Four drainages yielded high chromium or chromium and nickel values which can be attributed to exposures of serpentinite in the basins. Anomalous cobalt, copper, and silver values occur in sediment samples (BBD-6 and 9) from Black Butte River. Although the drainages encompass more than one Franciscan unit, the sediment samples are both located within the melange unit. Lenses and "knockers" of greenstone and diabase within the melange contain anomalous concentrations of copper (see table 1, BBH-4, 45, 59, and ECH-60) as well as trace amounts of silver (USBM data) which could provide a local source for these metals in the sediment samples. A similar source for the cobalt anomaly is probable because of its natural association with copper and silver. Anomalous concentrations of copper, cobalt, and gold are present in stream-sediment samples located in Elk Creek (ECR-5 and USBM sample) and Mendenhall Creek (ECR-14, 15, and 17). These anomalies can be attributed to sources similar to the Black Butte River sediment samples as well as manganiferous chert lenses within the Elk Creek drainage basin which contain cobalt, copper, and gold. Additionally, anomalous concentrations of cobalt are present in samples of ultramafic rock located in the headwaters of Mendenhall Creek. High boron values in sediment samples from Mendenhall and Sportsman Creeks are probably due to the presence of detrital tourmaline in samples of Franciscan sandstone from the same area.

The results of atomic-absorption analysis of bedrock samples indicate a high background level (0.2 ppm) of silver in both roadless areas. Samples from all lithologies and map units possess silver values that are uniformly higher than average crustal abundance of 0.1 ppm (Parker, 1967) or the average value for basalt or shale (Krauskopf, 1967). Two samples exceed a threshold value of 0.36 ppm silver, but the replicate analyses are only slightly higher than background level. Semiquantitative spectrographic analyses identify only four samples that contain measurable silver in both sample splits. The four samples (BBH-26, ECH-9, 38, and 78) are widely spaced and composed of sandstone belonging to three different units of the Franciscan assemblage. Minor amounts of organic matter in the sandstone samples could account for the silver content. Alternatively, the presence of minor pyrite and a common proximity to fault zones (all samples are within 2,000 ft of faults) may be the source of the silver enrichment. The regionally high background level obtained by the more sensitive atomic-absorption analytical technique possibly reflects elevated crustal temperatures produced regionally by late Cenozoic volcanism in the Clear Lake area 25 mi to the south.

Most gold present in the study areas is associated with either manganiferous chert or ultramafic rock. Small amounts of gold are present in two sandstone samples (ECH-56 and BBH-3) from the melange of the Central belt, a sample of tuffaceous shale (ECH-57) from the Bald Mountain unit, and a sample of volcanic sandstone (ECH-46) overlying a manganiferous chert lens in the Sanhedrin Mountain unit. Mercury associated with the gold values is present in concentrations near average crustal abundance (0.1 ppm) (Parker, 1967), and there is no spatial clustering of the gold-bearing samples. Disseminated pyrite is present in one gold-bearing sandstone sample from the melange, and minor quartz veining is present in the other samples. A disseminated gold deposit was recently discovered at Knoxville, Napa County, 65 mi southeast of the study areas. There, gold is associated with mercury in an area of Tertiary volcanism and hydrothermal activity. The gold in that area is thought to result from circulation of heated connate water high in chloride, carbon dioxide, and silica and containing abundant hydrocarbons, which mobilized and concentrated the gold and

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[1] Aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, chromium, cobalt, columbium, copper, gallium, gold, hafnium, indium, iron, lanthanum, lead, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, platinum, rhenium, scandium, silicon, silver, sodium, strontium, tantalum, tellurium, thallium, tin, titanium, vanadium, yttrium, zinc, and zirconium.

mercury in late Mesozoic sedimentary rock units (Vredenburgh, 1982). Though small amounts of gold are present in sedimentary rocks of the study areas, the lack of anomalous mercury concentrations and the absence of any indication of hydrothermal activity suggest that there are no Knoxville-type deposits in the area.

Samples of ultramafic rock from the serpentinite unit contain naturally high concentrations of chromium, nickel, and platinum-group elements (Pt, Pd, and Rh). Analysis of one of the most highly mineralized rocks, a chromitite nodule, yielded values that are an order of magnitude less than those considered to indicate significant metallic potential. The presence of concentrated chromite segregations is generally required in significant chromite occurrences (N. J Page, oral commun., 1982). Reconnaissance of the serpentinite bodies did not reveal appreciable chromite segregations.

The remaining metallic anomalies are associated with lenses and "knockers" of manganiferous chert and volcanic rock present within the individual map units of the Franciscan assemblage. The anomalies and any mining activity are discussed below for each map unit.

Mineralization in the melange of the Central belt was largely confined to "knockers" of manganiferous chert, tuffaceous greenstone, metagreenstone, and diabase. Anomalous elements in the "knockers" consist of minor manganese, copper, chromium, yttrium, and gold (see table 1, BBH-1, 45, 4, 59, and ECH-66). Along Forest Service Route M1, north of Monkey Rock, a narrow northwest-trending exposure of melange, bounded on the north by serpentinite and on the south by the Hull Mountain unit, contains mineralized blocks of greenstone, chert, and silica-carbonate rock. Also present are numerous "knockers" of diabase which may have been emplaced as sills. The diabase "knockers" are entrained parallel to bedding and a shear fabric in argillite and thin-bedded graywacke. Slightly anomalous concentrations of chromium are present in chilled areas near the margin of the diabase bodies (ECH-75); no bake zone is visible, but any that may have been present in the country rock probably has been destroyed by shearing. Similar diabase (ECH-60 and 62) with anomalous chromium and copper is present near Bald Mountain. One sample of silica-carbonate rock (ECH-81) from the melange exposed north of Monkey Rock had anomalous concentrations of cobalt, chromite, nickel, strontium, and mercury. Blocks of greenstone and chert contained abundant pyrite and carbonate but had low levels of metallic elements.

Within the Hull Mountain unit two samples from a manganiferous chert lens exposed in Elk Creek contain anomalous but minor amounts of manganese, copper, and gold. The chemistry of the samples (ECH-26 and 27) suggests a sea-floor hydrothermal origin for the anomalous metals (Bonatti and others, 1972; Crerar and others, 1982). This origin is discussed in more detail below. A small lens of pillow basalt exposed in Mendenhall Creek shows minor concentrations of chromium and strontium (ECH-30). The gabbroic intrusives at Monkey Rock contain small amounts of disseminated pyrite, but analyses show no concentrations of metals. A one-inch-wide vein of vuggy quartz cutting a gabbroic dike contains 0.6 ppm mercury. No mineral concentrations were detected in the country rocks surrounding the intrusives, either in the chemical analyses or by petrographic study of the sandstones (Layman, 1977).

A siliceous manganiferous iron deposit associated with greenstone is reported 3 mi west of Haydon Rock (Trask, 1950) along Thatcher Creek. The descriptions for these prospects are similar to a deposit at an abandoned mine shaft south of Bald Mountain. The shaft is 0.5 mi east of the Elk Creek Roadless Area boundary and appears on the topographic map (see sec. 4, T. 20. N., R. 10 W., Hull Mountain 7.5' quadrangle). There is no published account of a mine or prospect for that location. Although the shaft is collapsed, it appears to have been sunk vertically for 10 ft in a lens or "knocker" of metamorphosed manganiferous tuff which crops out over an area, approximately 15 by 30 ft, within the metasandstone of Bald Mountain. Pyrite, quartz, and minor malachite are present along shear planes in the tuff, and abundant quartz veins contain minor sphalerite. The manganese minerals are finely disseminated throughout the tuff.

Mineralized areas within the metasandstone and metavolcanic rocks of Black Butte are present at the Black Butte copper claim, located near Copper City, 4 mi east of the Black Butte Roadless Area (see fig. 2, No. 1). Disseminated cuprite is reported, presumably within metavolcanic rocks, with no associated vein system or any known production (Eric, 1948). The general area of the claim was examined and sampled during this study. The mineralized area is underlain by metamorphosed manganiferous volcanic tuff and chert belonging to the metasandstone and metavolcanic rocks of Black Butte. Small veinlets, 0.1 in. thick, of specular hematite and calcite cut across the schistosity of the metachert. Very minor blue copper staining occurs along fracture surfaces in metatuff. Manganese is present as finely disseminated oxide. The samples analyzed contained approximately 10 percent Fe, minor Mn and Ba, and rare Cu, Co, Cr, La, Ni, Y, and Au (see table 1, BBH-22, -23, -27, and -24). The mineralized rock is exposed in several small prospect pits in the immediate vicinity of Copper City. No extension of the deposit was seen in roadcut exposures to the north, west, or south.

Three known manganese deposits occur in the cherts of the Sanhedrin Mountain unit, but none are within the roadless area boundaries. Consolidated Claims and Impassable Rock deposits are 0.5 mi and 2 mi, respectively, from the boundary of the Elk Creek Roadless Area (see fig. 2, No.3 and No. 4). Host rocks at this deposit are massive white cherts and thin-bedded shaly cherts which enclose beds of siliceous manganese oxides averaging 25 to 30 percent manganese (Trask, 1950, p. 116-118). The Consolidated Claims produced less than 149 tons of black manganese oxide ore (Trask and others, 1943). A greenstone "intrusion" is reported at the Impassable Rock deposit with ore bodies composed of manganese carbonate and siliceous manganese oxide (Trask, 1950). The Gravelly Valley deposit occurs 3 mi south of the Elk Creek Roadless Area in a small ravine above the Ericson Ridge road (see fig. 2, No. 5). The deposit was investigated in 1942 by M. D. Crittenden, Jr. (Trask, 1950) and reexamined during this study. Manganese concentrations are exposed at the west face of an open pit within an isolated chert lens and consist of "knots" of black manganese oxide within folded recrystallized chert and interbedded tuffaceous cherty shale. The "knots" are in brecciated areas of the chert, in hinge areas of folds, and along small faults. Thin quartz and white calcite veinlets crisscross the ore creating a boxwork filled with crumbly black manganese oxide. The manganese minerals are poorly crystallized and some amorphous oxides are present. Small shiny black crystals of cryptomelane, identified by X-ray diffraction, are present within the ore. Romanicite, lithiophorite, and pyrolusite may also be present (M. B. Norman, written commun., 1982). In addition to manganese, trace-element geochemistry reveals the presence of anomalous values of barium, copper, nickel, strontium, zinc, cobalt, molybdenum, and gold. The Gravelly Valley deposit was actively mined during World War II with a production of less than 149 tons (Trask and others, 1943).

The geology of the Gravelly Valley occurrence indicates a post-depositional episode of mineralization which concentrated the ore into open fractures created by folding and faulting. The deformation, which fractured the rocks, must have occurred after the chert beds were lithified. The Gravelly Valley locality is along a major, high-angle fault zone, the Hot Springs shear zone (Etter, 1979), which is in turn associated with active thermal springs. Hydrothermal activity along the fault zone may have acted to mobilize and concentrate base metals, producing areas of mineralized rocks at this locality.

The trace-metal chemistry of the manganiferous cherts from the four Franciscan units are all similar to sea-floor hydrothermal iron-manganese deposits forming in present-day oceans. These occurrences are characterized by relatively low concentrations of nickel, cobalt, and copper and high concentrations of barium (Bonatti and others, 1972). Recent studies of manganiferous cherts of the Franciscan Central belt indicate a sea-floor hydrothermal origin for the manganese concentrations (Crerar and others, 1982). The field relations within the Sanhedrin Mountain and Hull Mountain units suggest that in addition to sea-floor hydrothermal activity, gabbroic intrusions and late Cenozoic hydrothermal activity may have acted to concentrate base metals within chert.

No commercial producer of sand and gravel is located in the study areas (Rapp, 1979, p. 11, 12). Gravel pits 3 mi east of Covelo and 13 mi northwest of the Elk Creek study area have supplied road-building material for local use only. Sand and gravel deposits along Elk Creek and Black Butte River are too small and isolated to compete with larger deposits closer to markets. Graywacke-sandstone which underlies much of the area is too fractured to be used as dimension stone.

Geothermal activity

Evidence of geothermal activity is lacking in the roadless areas except for two gaseous springs on the north side of Sanhedrin Mountain. The springs issue hydrogen sulfide gas (California Department of Water Resources, 1969) and are associated with northwest-trending faults. Carbon dioxide-rich springs are present 5 mi south of the Elk Creek Roadless Area and along a linear trend for 30 mi to the southeast (Barnes and others, 1975). One spring, located 16 mi south of the roadless area, is hot (41°C), the others are warm (13°-18°C) (Berkstresser, 1968; Thompson and others, 1981). The trend of these thermal springs corresponds to the Hot Springs shear zone (Etter, 1979) which was assigned to the Bartlett Springs fault zone by McLaughlin and others (1982). Geologic mapping indicates this fault zone continues north into the Elk Creek area, where hydrogen sulfide gas issues from a few springs along its trend.

Hydrogen sulfide has several possible sources, some of which are the result of geothermal activity (Brook, 1981). Spring temperature data suggest a northward cooling trend along the Bartlett Springs fault zone. No known hot springs are present near the fault zone north of Lake Pillsbury. No zones of hydrothermal alteration were found in either roadless area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Geochemical analyses of the bedrock and stream-sediment samples indicate that all of the mapped units contain small areas where concentrations of metallic elements are anomalous; that is, higher than both calculated background levels and average crustal abundances. However, no areas of extensive alteration are present, and metallic concentrations at mineralized localities are not significant. No mines or prospects are present in the study areas. No oil or gas seeps, coal seams, or radioactive minerals were detected within the study areas. The low porosity and permeability of Franciscan sandstones that occur in the area indicate a very low potential for oil and gas. Based on a lack of alteration, lack of thermal springs, no evidence of geologically recent volcanism, and normal values of heat-flow measurements, the geothermal energy potential for the area is low. Hydrogen sulfide gas is vented from a few springs along Sanhedrin Creek, but the geothermal significance of this H_2S is uncertain.

The most significant anomalous concentrations of metallic elements are from samples of chert, volcanic rock, and ultramafic rock. The mineral resource potential depends on the volume of these lithologies present and the degree to which they are mineralized.

The metavolcanic rocks at Black Butte unit and the cherts of the Sanhedrin Mountain unit are the most laterally extensive rocks possessing anomalous manganese concentrations. The boundaries of the roadless areas are such that the potential for undiscovered manganese deposits within these units lies generally outside the areas. Limited manganese ore production is documented for mineralized cherts on Sanhedrin Mountain. The metavolcanic rocks at Black Butte have been prospected for copper, but no ore was produced. Because of the limited ore production and small amount of mineralized rock observed, only a low resource potential for manganese and associated metals is indicated for these units.

Due to the combined effects of their small size, and low concentration of metals, the manganiferous cherts in the Hull Mountain unit and melange of the Central belt have a very low resource potential. For similar reasons, mineralized greenstone lenses and "knockers", which occur in these units as well as the Black Butte and Bald Mountain unit are not considered to have significant resource potential. There may be some unknown potential for copper within large lenses of greenstone (as much as 0.5 mi wide by 1.5 mi long) which occur east of Bald Mountain outside the study areas.

A low resource potential is indicated for chromium, nickel, and platinum-group resources present in the ultramafic rocks of the area, since significant chromite segregations are lacking in the sampled serpentinite bodies. A higher resource potential is possible for the serpentinite bodies north of the Elk Creek Roadless Area in the Bennett Valley area. The southern extension of these serpentinites lies within the roadless area boundaries, but they were not visited during this study. No chromite prospects are known to exist for these serpentinites (M. C. Stinson, oral commun., 1982). Hence, the potential for chromium and related metals is low.

No significant potential for gold or silver resources is indicated. Concentrations of these metals are either very low or from small lenses or blocks with limited tonnage. Indicators of precious-metal deposits, such as anomalous mercury concentrations or hydrothermal alteration, are lacking.

REFERENCES CITED

Barnes, I., Irwin, W. P., and Gibson, H. A., 1975, Geologic map showing springs rich in carbon dioxide or chloride in California: U.S. Geological Survey Water-Resources Investigations open file map, scale 1:500,000.

Berkstresser, C. F., Jr., 1968, Data for springs in the northern Coast Ranges and Klamath Mountains of California: U.S. Geological Survey open-file report, 49 p.

Blake, M. C., Jr., Irwin, W. P., and Coleman, R. G., 1967, Upside-down metamorphic zonation, blueschist facies, along a regional thrust in California and Oregon: U.S. Geological Survey Professional Paper 575-C, p. C1-C9.

Berry, K. D., 1981, New age determinations in Franciscan limestone blocks, northern California: Abstracts with program, Fifty-seventh annual meeting, Pacific sections, AAPG, SEG, and SEPM.

Blake, M. C., Jr., Jayko, A. S., and Howell, D. G., 1981, Geology of a subduction complex in the Franciscan assemblage of northern California: Oceanologica Acta, 1981, N^{O}SP, Proceedings of the 26th International Geological Congress, Geology of Continental Margins Symposium, Paris, July 7-17, p. 267-272.

Blake, M. C., Jr., and Jones, D. L., 1974, Origin of Franciscan melanges in northern California: Society of Economic Paleontologists and Mineralogists Special Publication 19, p. 345-357.

Bonatti, E., Kraemer, T., and Rydell, H., 1972, Classification and genesis of submarine iron manganese deposits; in Horn, D., ed., Ferromanganese deposits on the ocean floor: Washington, National Science Foundation, p. 149-165.

Brook, C. A., 1981, Variability and sources of hydrogen sulfide and other gases in steam at The Geysers; in McLaughlin, R. J., and Donnelly-Nolan, J. M., eds., Research in the Geysers-Clear Lake area, northern California: U.S. Geological Survey Professional Paper 1141, p. 193-203.

California Department of Water Resources, 1966, Engineering geology of Dos Rios-Grindstone Tunnel: unpublished office report.

______ 1968, Areal geology Hayshed-Grindstone and Elk-Grindstone tunnels: unpublished map.

_____ 1969, Areal geology, Elk Creek tunnel: unpublished office report.

California Division of Mines and Geology, 1978, Aeromagnetic maps of the north coastal area, California: Open-File Report 78-13E, SAC, 11 sheets, scale 1:62,500.

Crerar, D. A., Namson, J., So Chyi, M., Williams, L., and Fergenson, M. D., 1982, Manganiferous cherts of the Franciscan assemblage: I. general geology, ancient and modern analogues, and implications for hydrothermal convection at oceanic spreading centers: Economic Geology, v. 77, no. 3, p. 519-540.

Eric, J. H., 1948, Tabulation of copper deposits in California, in Jenkins, O. P., ed., Copper in California: California Division of Mines Bulletin 144, p. 199-387.

Etter, S. D., 1979, Geology of the Lake Pillsbury area, northern Coast Ranges, California: University of Texas, Austin, Ph.D. thesis, 314 p.

Grimes, D. J., and Marranzino, A. P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.

Irwin, W. P., 1960, Geologic reconnaissance of the northern Coast Ranges and Klamath Mountains, California, with a summary of the mineral resources: California Division of Mines Bulletin 179, 80 p.

Jordan, M. A., 1975, Geology of the Round Valley, Sanhedrin Mountain area, northern California Coast Ranges: University of Texas, Austin, Ph.D. thesis, 174 p.

Krauskopf, K. B., 1967, Introduction to geochemistry: New York, McGraw-Hill 721 p.

Lachenbruch, A. H., and Sass, J. H., 1980, Heat flow and energetics of the San Andreas fault zone: Journal of Geophysical Research, v. 85, no. B11, p. 6185-6222.

Layman, E. B., 1977, Intrusive rocks in the near-trench environment: two localities in the northern California Franciscan complex: Stanford University,Calif. M.S. thesis, 55 p.

Lehman, D. H., 1974, Structure and petrology of the Hull Mountain area, northern California Coast Ranges: University of Texas, Austin, Ph.D. thesis, 126 p.

Le Peltier, C., 1969, A simplified statistical treatment of geochemical data by graphical representation: Economic Geology, v. 64, p. 538-550.

McLaughlin, R. J., Ohlin, H. N., and Thormahlen, D. J., 1984, Geologic map and structure sections of the Little Indian Valley-Wilbur Springs geothermal area, northern Coast Ranges, California: U.S. Geological Survey Miscellaneous Investigations Series Map, scale 1:24,000 [in press].

Page, N. J, Cassard, Daniel, and Haffty, Joseph, 1982, Palladium, platinum, rhodium, ruthenium, and iridium in chromitites from the Massif du Sud and Tiebaghi Massif, New Caledonia: Economic Geology, v. 77, no. 6, p.1571-1577.

Parker, J., 1967, Crustal abundance of the elements 1-93: U.S. Geological Survey Professional Paper 440-D.

Rapp, J. S., Mines and mineral producers active in California during 1978: California Division of Mines and Geology SP-53, 1979, 25 p.

Thompson, J. M., Goff, F. E., and Donnelly-Nolan, J. M., 1981, Chemical analyses of waters from springs and wells in the Clear Lake volcanic area; in McLaughlin, R. J., and Donnelly-Nolan, J. M., eds., Research in The Geysers-Clear Lake area, northern California: U.S. Geological Survey Professional Paper 1141, p. 183-191.

Trask, P. D., 1950, Geologic description of the manganese deposits of California: California Division of Mines and Geology Bulletin 151, 378 p.

Trask, P. D., Wilson, I. F., and Simons, F. S., 1943, Manganese deposits of California - a summary report (including tabulated data on manganese properties of California), in Jenkins, O. P., ed., Manganese in California: California Division of Mines Bulletin 125, p. 51-215.

Van Trump, George, Jr., and Miesch, A. T., 1977, The U.S. Geological Survey RASS-STATPAC system for management and statistical reduction of geochemical data: Computers and Geosciences, v. 3, no. 3, p. 475-488.

Vredenburgh, L. M., 1982, Tertiary gold bearing mercury deposits of the Coast Ranges of California: California Geology, February 1982, p. 23-27.

Table 1. Geochemical data for anomalous samples from the Black Butte and Elk Creek Roadless Areas.

[Atomic-absorption analyses for Au, Zn, and Ag and gold-film analysis for Hg by R. Fairfield and J. Martin. Fire-assay and spectrographic analyses for Au, Pt, Pd, and Rh by R. R. Carlson and E. F. Cooley. Semiquantitative six-step spectrographic analyses by B. Adrian. All values in parts per million. Looked for but not found in anomalous quantities: Fe, Mg, Ca, Ti, As, Be, Bi, Cd, La, Nb, Pb, Sb, Sc, Sn, V, W, Ru, Ir, Th, Zr].

Stream-sediment samples

Element	Threshold value	BBD-1	BBD-2	BBD-6	BBD-9	ECR-2	ECR-5	ECR-6	ECR-8	ECR-13	ECR-14	ECR-15	ECR-17
B	110	---	---	---	---	---	---	---	200	150	150	150	---
Co	22	---	---	---	50	---	---	---	---	---	150	---	---
Cr	2100	3000	5000	---	---	5000	3000	5000	---	5000	5000	5000	3000
Cu	32	---	---	100	---	---	50	---	---	---	70	70	50
Ni	220	---	---	---	---	---	300	---	---	300	500	500	300
Ag	.4	---	---	.4	.6	---	---	---	---	---	---	---	---

Bedrock samples

Element	Threshold value	ECH-27	ECH-30	ECH-41	ECH-46	ECH-50	ECH-53	ECH-56	ECH-57	ECH-60	ECH-62	ECH-66	ECH-75
Mn	3100	5000	---	---	---	---	---	---	---	---	---	5000	---
Ba	4100	---	---	5000	---	---	---	---	---	---	---	---	---
Co	95	---	---	---	---	---	---	---	---	---	---	---	---
Cr	460	---	500	---	---	---	3000	---	---	---	500	---	500
Cu	100	300	---	---	---	---	---	---	---	150	---	---	---
Ni	220	---	---	---	---	---	2000	---	---	---	---	---	---
Sr	700	---	1000	---	---	---	---	---	---	---	---	---	---
Au	.05	.05	---	---	.10	.05	.005?	.1	.05	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	---
Pt	.010	---	---	---	---	---	.05?	---	---	---	---	---	---
Pd	.002	---	---	---	---	---	---	---	---	---	---	---	---
Rh	.004	---	---	---	---	---	.005	---	---	---	---	---	---

Bedrock cont.

ECH-80	BBH-3	BBH-4	BBH-16	BBH-17	BBH-24	BBH-59
---	---	---	---	---	---	---
---	---	---	---	---	5000	---
100	---	---	---	---	---	---
5000	---	---	3000	3000	700	---
---	---	500	---	---	300	150
500	---	---	1000	2000	---	---
---	---	---	---	---	---	---
.015	.05	---	.015?	.02?	---	---
---	---	---	---	---	---	---
.10	---	---	---	---	---	---
---	---	---	---	.002	---	---
.03	---	---	---	---	---	---

Mineralized bedrock samples[1]

Element	BBH-1	BBH-22	BBH-23	BBH-27	BBH-45	ECH-26	ECH-44	ECH-49	ECH-70B	ECH-81
Mn	5000	5000	5000	5000	5000	5000	5000	5000	---	---
Ba	---	---	3000	5000	---	---	---	5000	---	---
Co	---	---	100	---	---	---	150	200	---	150
Cr	---	---	500	---	---	---	---	---	---	5000
Cu	---	---	500	300	500	---	500	5000	---	---
La	---	200	---	300	---	---	---	---	---	---
Ni	---	---	500	---	---	---	---	1000	---	3000
Sr	---	---	---	---	---	---	---	1000	---	1500
Y	70	150	150	150	100	---	200	---	---	---
Au	.25	---	---	.05	.05	---	---	.65	---	---
Hg	---	---	---	---	---	---	---	---	.6	.6
Zn	---	---	---	---	---	---	270	450	---	---
Mo	---	---	---	---	---	---	---	70	---	---

[1] Samples BBH-22, BBH-23, and BBH-27 are from Black Buttes copper claim area. Sample ECH-49 is from the Gravelly Valley deposit. All other samples are from natural rock outcrops which appeared mineralized or altered in the field.

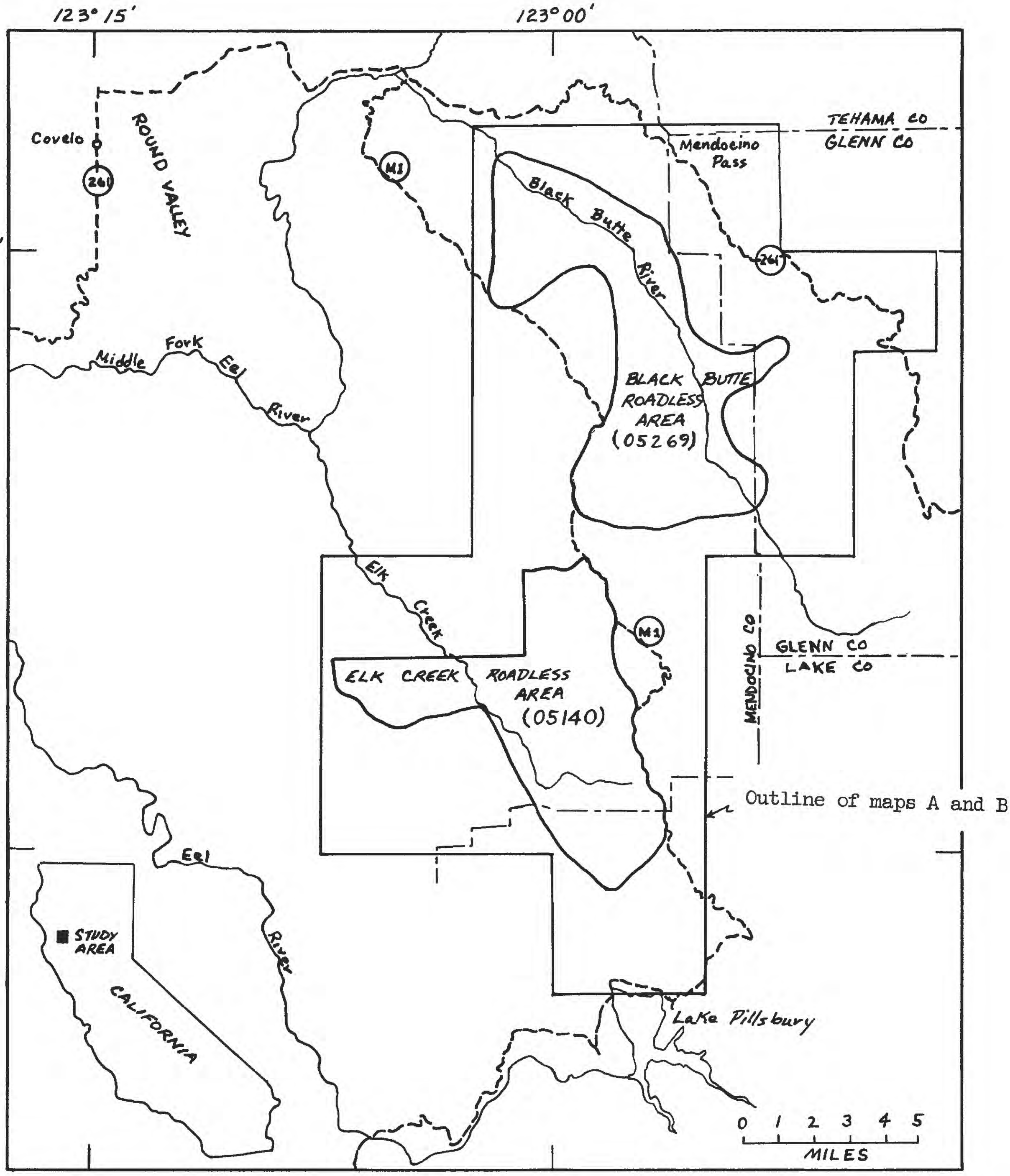

Figure 1. Index map showing location of the Black Butte and Elk Creek Roadless Areas, Mendocino, Lake, and Glenn Counties, Calif.

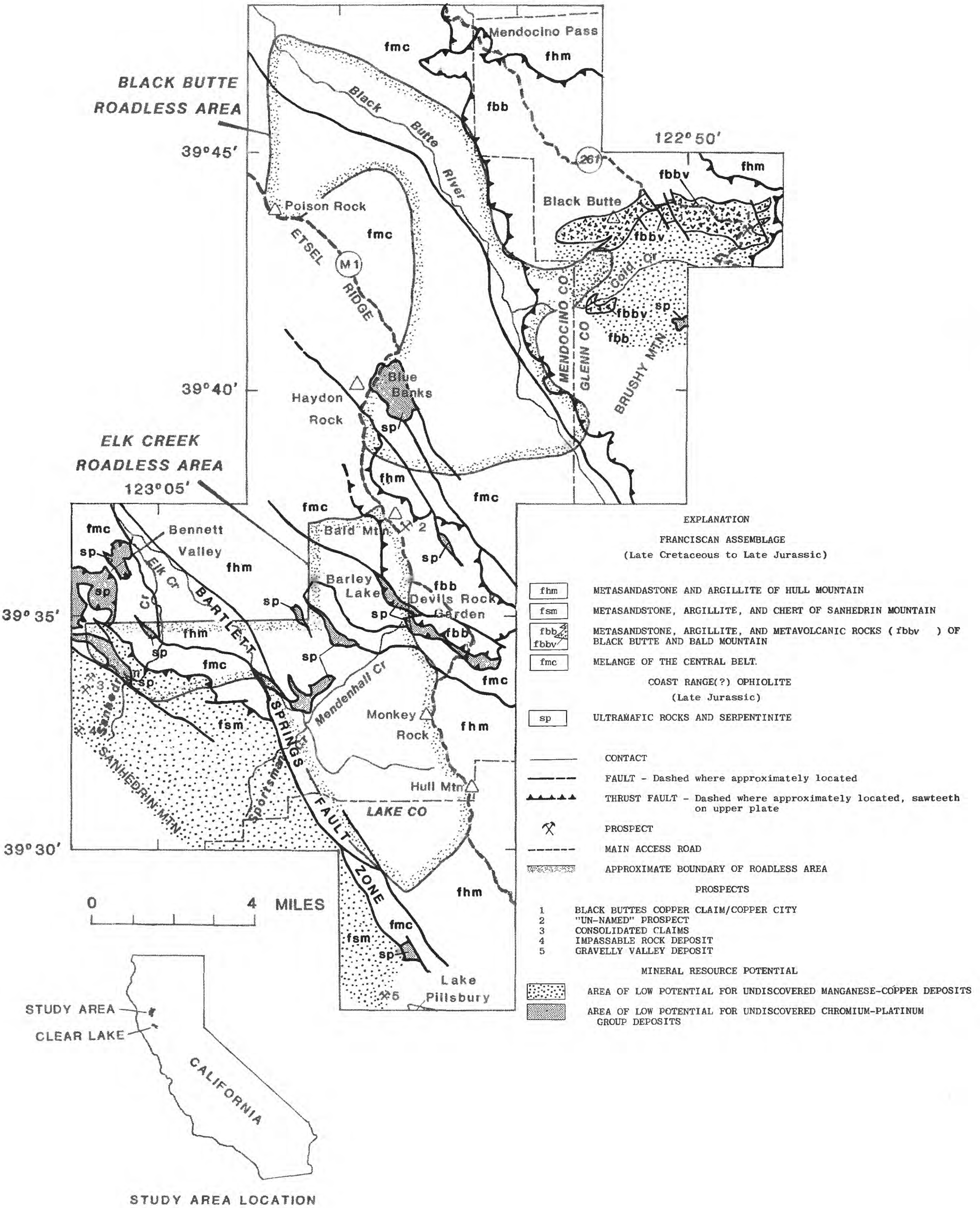

Figure 2. Mineral resource potential and simplified geology of the Black Butte and Elk Creek Roadless Areas, Calif. (geology mapped in 1980-81).