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Assessment of Mineral Resource Potential of the Western Half of the Redding 1:250,000 Quadrangle, Northwestern California

By

Miles L. Silberman,[1] Jerry R. Hassemer,[1]
Jennifer Force,[2] and Richard B. Tripp[1]

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[1]U.S. Geological Survey, P.O. Box 25046, MS 973, Federal Center, Denver, CO 80225
[2]Roy F. Weston, Inc., 3 Hawthorne Pkwy., Suite 400, Vernon Hills, IL 60061

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Miles L. Silberman, Jerry R. Hassemer, Jennifer Force, and Richard B. Tripp
U.S. Geological Survey, Denver, Colorado 80225

ABSTRACT

The western half of the Redding 1 x 2 degree quadrangle contains two physiographic provinces, the Klamath Mountains and the Coast Ranges. Both provinces are underlain by accreted oceanic and island arc terranes whose ages decrease from east to west. Accretion or amalgamation of the terranes occurred from the Devonian through the Early Tertiary. The terranes contain varying proportions of turbidite sandstone, mudstone, shale, greenstone, chert, minor limestone or their metamorphosed equivalents. The terrane boundaries are eastward-dipping thrust faults, some of which contain serpentinized ultramafic rocks.

The most significant difference between the two provinces is the occurrence of granitic to intermediate and mafic plutons and their hypabyssal offshoots of Devonian to Cretaceous age in the Klamath Mountains, and their absence in the Coast Ranges. However, a recently completed geophysical survey suggests that subsurface plutonic rocks may occur in the Coast Ranges (Griscom and others, in press).

Within the western half of the Redding quadrangle, the most common mineral deposits in the Coast Ranges and Klamath Mountains are Mn-chert deposits associated with mafic volcanic rocks. Small massive-sulfide deposits containing Cu, Zn and some Au and Ag occur in volcanic rocks and sedimentary rocks associated with the volcanics, more commonly occurring in the Klamath Mountains province than the Coast Ranges. Many larger examples of massive-sulfide deposits occur in the eastern half of the Redding quadrangle, and in the Weed quadrangle to the north of the Redding quadrangle. Small, mesothermal gold-quartz veins occur in a wide variety of lithologies in the western Klamath Mountains. Many larger gold-quartz vein deposits are common in the Klamath Mountains in the eastern half of the quadrangle. Placer gold and gold-PGE deposits occur mostly along the Trinity River and its tributaries in the Klamath Mountains. A few small isolated placers occur in the Coast Ranges. Areas of placer occurrence are much more widespread than lode gold deposits.

Small deposits consisting of disseminated auriferous copper sulfides, and copper sulfide veins hosted in serpentinite and diorite dikes, occur in both provinces but are more common in the Klamath Mountains. The largest of these, at Horse Mountain, yielded between 100,000 and 1,000,000 pounds of Cu and an unknown quantity of Au (Eric, 1948). A few small podiform chromite deposits occur in ultramafic complexes in both provinces.

We compiled occurrences and descriptions of these mineral deposits in the western half of the Redding quadrangle and summarized their common

characteristics. We summarized geochemical data from the various mines and prospects in the area. We summarized stream sediment and panned concentrate geochemistry and mineralogy, and defined geochemical anomalies in stream sediments and panned concentrates that are characteristic of areas containing the various types of mineral deposits. We combined all these data with geophysical characteristics of the areas containing deposits and have defined regions that we believe are favorable for the occurrence of, as yet, undiscovered mineral deposits containing Au, Cu, Mn, and chromite.

INTRODUCTION

This mineral resource assessment of the western half of the Redding 1 x 2 degree quadrangle is a product of the USGS reconnaissance geological, geochemical, and geophysical study under the CUSMAP program that began in the early 1980's under the direction of John Albers. Initially, the senior author was assigned the task of carrying out the regional geochemical stream sediment and litho-geochemical survey of the quadrangle. With the untimely death of John Albers in 1986, the senior author was given the additional responsibility of coordinating the entire project and producing this mineral resource potential report.

Mandated reports on regional geochemistry of stream sediment and rock samples for the western half of the quadrangle are published (Smith and others, 1990, 1991; Hassemer and others, 1992a, 1992b). A number of components have been used to produce the mineral resource potential maps:

(1) Geologic map of the Redding quadrangle (Fraticelli and others, 1987) and derivative maps showing terranes, plutons, and ultramafic rocks, produced in part, by modifications of the geologic map, either by Fraticelli and others (1987), or the authors.

(2) Compilation of mines and prospects locations along with information on the type of deposit and commodities present in the western half of the quadrangle (this work).

(3) Geochemical data for stream sediments and panned concentrates for the western half of the quadrangle (Smith and others, 1990, 1991) and a basic statistical summary of those data, along with interpretation of stream-sediment geochemical characteristics in areas that contain mineral deposits (Silberman and Hassemer, 1990; Silberman and others, 1991; this work).

(4) Geochemical data for rocks, particularly mineralized rocks from the western half of the quadrangle (Silberman and Danielson, 1991; Hassemer and others 1992a and 1992b).

(5) Aeromagnetic and gravity maps, and an interpretive map showing magnetic boundaries within the Redding quadrangle (Griscom and others, in press).

A qualitative assessment scheme based on combinations of the above components, modified from that used by Silberman and Hassemer (1990) for a mineral resource assessment of Spotted Owl Habitat regions in northwestern California, was constructed and forms the basis for the "hot dog" style mineral resource assessment maps. Because we feel that the Redding area cannot be interpreted outside of the context of the regional geology and metallogeny that it forms a part of, we will describe the general geologic setting and mineral deposits of northwestern California in this initial section of the report.

ACKNOWLEDGEMENTS

We dedicate this work to John Albers, Porter Irwin, and Preston Hotz who were here before us and provided the geologic framework and mineral deposit background for the assessment that we are attempting to construct. We hope that our field investigations and compilation added to their data base, and that this work, along with theirs will generate further study of this difficult but intriguing area. Stream-sediment sampling, one of the important components of this assessment was carried out by students of Humboldt State University, Arcata, Calif., under contract to the USGS. Crew chiefs were Buck King and David Miller. They carried out sampling under extremely difficult logistical conditions in some of the most rugged and remote terrane in Northern California. Professor Donald Garlick of H.S.U. supervised the sampling operations. Professor Garlick and W. Porter Irwin of the USGS reviewed earlier versions of this manuscript.

REGIONAL GEOLOGIC SETTING

Geology of Northwestern California

The Redding quadrangle is located in northwestern California in an area of complex and not thoroughly understood geology. Plate tectonic theory has provided a framework for understanding some of this complexity. Northwestern California is divided into two main geographic provinces, the northern Coast Ranges and the Klamath Mountains (fig. 1). The Redding quadrangle also contains part of the Great Valley province.

The Coast Ranges and Klamath Mountains provinces are composed of a complex assortment of discrete packages of rocks referred to as "terranes" or "tectonostratigraphic terranes." The region was constructed from a sequence of subduction and accretion (amalgamation?) events that joined these terranes together. Details of the various plate tectonic models used to explain this process vary, but as Albers (1981, p. 768) stated "they all agree with the fundamental thesis that various assemblages of oceanic and island arc crust have been accreted to older sialic crust...." The old sialic crust does not now occur in northwestern California, but evidence of its former presence occurs in detrital material in some of the older units in the eastern Klamath Mountains (Wallin and others, 1988). The discrete terranes and subterranes within them are characterized by specific types of mineral deposits, or in the case of some terranes, by the absence of mineral deposits (Irwin, 1972; Albers, 1981).

The western half of the Redding quadrangle (fig. 2) contains part of the Coast Ranges and the western part of the Klamath Mountains in approximately equal proportions. Both of these provinces will be briefly described in the next section.

GENERAL GEOLOGY OF THE REDDING QUADRANGLE

The Klamath Mountains

The southern Klamath Mountains in the Redding 1 x 2 degree quadrangle consist of a series of "terranes" or belts of rock that form thrust plates in a generally eastward-dipping sequence (Irwin, 1972, 1981, 1985). The terranes consist of island-arc and oceanic volcanic and sedimentary rocks including turbidite sandstone, mudstone, shale, greenstone, chert, minor limestone and their metamorphosed equivalents that formed during Ordovician through Jurassic time. The Eastern Klamath terrane (fig. 2), the nucleus of the Klamath Mountains to which the other terranes were joined, was formed during long standing volcanic-arc activity that extended from the Devonian through the Jurassic (Irwin, 1981). This Eastern Klamath terrane (EKT)[1] was built on Ordovician oceanic crust and upper mantle, now represented by the Trinity terrane (TT). Along the western edge of the EKT, the Central Metamorphic terrane (CMT, fig. 2) developed during Devonian subduction beneath the TT. Subsequently, during middle to late Jurassic time, the North Fork (NFT), Hayfork (EHT and WHT), Rattlesnake Creek (RCT), and Western Jurassic terranes (WJT) were then amalgamated (joined) to the combined EKT and CMT by successive subduction events (Irwin, 1981, 1985).

The terrane boundaries are thrust faults, which commonly contain ultramafic bodies, many of which are now serpentinized. Most of the serpentinites are parts of ophiolites which were deformed during terrane amalgamation and (or) accretion. Deformation during these processes led to dismemberment, remobilization, and emplacement of the serpentinites along the regional terrane boundaries and other thrust faults. The serpentinites are strongly magnetic and their subsurface extent, which in many areas is much larger than their outcrop areas, is well delineated on aeromagnetic maps (Griscom and others, in press).

Granitic, intermediate, and mafic plutons and associated hypabyssal rocks of Devonian through Cretaceous age intrude the rocks of many of the terranes. They occur in belts of equivalent age that generally follow the overall trends of the amalgamated terranes (Irwin, 1985; fig. 3). Some plutons and plutonic belts were emplaced before the host terrane was joined to an adjacent terrane and are hence, "pre-amalgamation." Most of these are either parts of ophiolites or are co-magmatic with volcanic rock sequences that formed in the same island arc. An example of this is the middle Jurassic Ironside Mountain batholith belt (fig. 3) in the Western Hayfork terrane which is comagmatic with a regionally extensive meta-andesite unit that underlies a large part of the terrane (Irwin, 1985). There are plutons and plutonic belts that are clearly post-amalgamation, as they are significantly younger than the wall rocks in their host terranes, based on isotopic ages, or they cut across terrane boundaries (Irwin, 1985). The early Cretaceous

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[1]A tabulation of abbreviations for terranes used in the text and other figures is part of figure 2.

Shasta Bally batholith, and the belt of plutons in which it occurs are post-amalgamation (Irwin, 1985; fig. 3).

Regional metamorphic grade of the volcanic and sedimentary rocks of the terranes ranges from sub-greenschist facies to almandine-amphibolite facies (Davis, 1966). Metamorphosed rocks of variable grade are present in all of the terranes. Contact metamorphism has affected rocks adjacent to plutons, particularly post-amalgamation intrusions, as exemplified by the banded gneiss zones along the contacts of the Shasta Bally batholith with its wall rocks (Albers, 1964).

Superjacent rocks (those that depositionally overlie the amalgamated terranes) include sedimentary and volcanic rocks of Cretaceous and Tertiary age. Most of these occur in the Great Valley physiographic province (fig. 2).

Most of the terranes of the Klamath Mountains province contain similar lithologies, although the proportions differ. A few, such as the Rattlesnake Creek and Central Metamorphic terranes are unique. The former is largely dismembered ophiolite, the latter is a complex of mafic and felsic gneisses and schists. Some terranes such as the Rattlesnake Creek, North Fork, and Eastern Hayfork terranes are melanges or contain a significant melange component. The melanges are chaotic mixtures of varied oceanic or island-arc lithologies in a serpentinous or shaly matrix. Fraticelli and others (1987) describe individual formations, including plutons, in the terranes. Their geologic map was the basis for figure 2.

Geology of the Coast Ranges

The Coast Ranges province forms most of the northern and central parts of coastal California (figs. 1, 2). Most of it consists of the Franciscan assemblage of Jurassic to Early Cretaceous age (Blake and Jones, 1974). The very complex assemblage of oceanic rocks is divided generally into three sub-parallel terranes separated by eastward dipping thrust faults. On figure 2, two of these terranes are further subdivided. The easternmost, structurally highest terrane combines the Pickett Peak and Yolla Bolly terranes which are made up of generally well bedded Jurassic to early Cretaceous graywacke and mudstone with interbedded chert and metavolcanic rocks. The westernmost, the combined Coastal terrane, and the Yager terrane (fig. 2) consist of Late Cretaceous to Eocene massive arkosic sandstone and mudstone alternating with bedded flysch sandstone and mudstone with little chert and volcanic rock.

The Central terrane lies structurally between these two and consists of a series of melanges containing very large, coherent blocks of metagraywacke that can be up to tens of kilometers in maximum dimension. In most of the Central terrane, lithologies are mixed and consist of metagraywacke, metachert, greenstone, serpentinite, and isolated blocks of blueschist and eclogite set in a matrix of sheared and quartz veined mudstone, sandstone, and serpentinite (Blake and Jones, 1974). Metamorphic grade varies in the belts. In the Pickett Peak–Yolla Bolly terranes, it increases to the east towards the Coast Ranges thrust (fig. 1) which constitutes the boundary between the two provinces. The

South Fork Mountain Schist, which forms most of the Pickett Peak terrane of figure 2, is characterized by blue-schist facies metamorphism (Blake and others, 1989). The Central terrane is generally prehnite-pumpelleyite facies metamorphic grade except for the higher grade exotic blocks. The Coastal terrane is of lower metamorphic grade than the rest of the Franciscan assemblage (Blake and Jones, 1974). Superjacent rocks, mostly consisting of sedimentary lithologies of Late Miocene to Pliocene Age overlie the Franciscan assemblage in the western part of the quadrangle (fig. 2).

The Coast Ranges ophiolite, lies along the Coast Ranges thrust and forms its hanging wall. It consists of a discontinuous sheet of serpentinized ultramafic rocks, gabbro, diabase, pillow lavas, and cherts. It structurally overlies the Franciscan assemblage along the west side of the Great Valley. In the Redding quadrangle, the Elder Creek terrane includes this ultramafic complex. These ultramafic rocks, which host important metal deposits, are overlain by Late Jurassic to Cretaceous sedimentary rocks of the Great Valley sequence, mudstones, sandstone, conglomerate, and shale, which on figure 2 are included with the superjacent rocks of the Great Valley province. The Great Valley sequence rocks are coeval in age to much of the Franciscan assemblage but have more continuity of lithologic units, are less deformed, contain less volcanic component, and are essentially unmetamorphosed (Blake and Jones, 1974; Bailey and others, 1964).

Similar lithologies, and presence of ultramafic rocks within and along structural contacts, are common characteristics of the Coast Ranges and the Klamath Mountains. Perhaps the most significant difference between them is the lack of granitic plutons in the Franciscan (Irwin, 1960). Recent geophysical work, done as part of this project, however, suggests the probable presence of plutons in the subsurface within the Central terrane of the Coast Ranges (Griscom and others, in press). The tectonic history of the Franciscan assemblage and its relationship to the Klamath Mountains and Great Valley sequence are the subjects of much current study.

The Coast Ranges thrust is essentially continuous from the Bay Area north to southern Oregon. It separates the Franciscan assemblage from the Great Valley sequence in the south, and from the Klamath Mountains to the north of 40° 15' N. The Josephine ophiolite, which forms the basal part of the Western Jurassic terrane (fig. 2) occupies a similar structural position to that of the Coast Ranges ophiolite (Irwin, 1981; Jennings, 1977). Between about 38 and 39° N the Coast Ranges thrust is displaced by post Mesozoic faulting related to the San Andreas system (Albers, 1981; fig. 1). This area contains two sequences of volcanic rocks, the Tertiary Sonoma Volcanics, and the Quaternary Clear Lake Volcanics. Significant thermal spring activity and both Hg and Au deposits occur there (Albers, 1981; Lehrman, 1986).

The Coast Ranges and Klamath Mountains are parts of the complex of accreted, exotic terranes that form the margin of North America from Alaska to Mexico (Coney and others, 1980). The process of joining these terranes to the North American craton, in the region of northern California, appears to have started in the Devonian, and was completed by the late Cretaceous or early Tertiary (Irwin, 1989; Blake and Harwood, 1989). The Great Valley province is an elongate structural trough extending from approximately Redding south to the Tehachapi Mountains. It contains Jurassic to recent sedimentary rocks and sediments (Hackel, 1966). It is younger than the two other physiographic provinces, and evolved after the emplacement of their component terranes in North America. Because the Great Valley is not part of the western half of the Redding quadrangle, it will not be discussed further.

MINERAL DEPOSITS

In northwestern California, the Klamath Mountains have a larger mineral endowment and a greater variety of deposits than the Coast Ranges. The western half of the Redding quadrangle contains subequal parts of the Coast Ranges and the Klamath Mountains (fig. 2). Most of the mineral deposits with the exception of a roughly equal numbers of Mn-chert deposits are in the Klamath Mountains. The reasons for the unequal distribution are not obvious, as other parts of the Franciscan assemblage, south of this area, are well endowed with a variety of mineral deposits (Albers, 1981; Davis, 1966).

Mineral deposits both by size and variety are not evenly distributed (Irwin, 1972; Albers, 1981). A general description of mineral deposits in the Klamath Mountains and Coast Ranges follows. We will briefly describe some of the major deposit types that occur in the eastern half of the quadrangle even though only small examples of those types occur in the western half. Our assessment depends in part on rock and stream-sediment geochemistry, which was partly defined from samples taken within mineralized areas and districts in the eastern half of the quadrangle that are more numerous and generally larger than those in the western half.

Mineral Deposits of the Klamath Mountains

The Klamath Mountains have produced significant amounts of Au, and combined Cu, Zn, and Pb. Pyrite, Ag, Cr, and Hg have also been important but of lessor amount. Platinum and Mn have been produced in minor quantity (Albers, 1966). Some Fe production also has been recorded (Gay, 1957). The most important products have been gold from placers and lode deposits and Cu, Zn, and Pb with byproduct Ag and Au from massive-sulfide deposits. The dollar amounts of Au and combined Cu, Zn and Pb are approximately equal at $140 million. Silver, the next most valuable metal had approximately $13 million production, and chromite had nearly $9 million production (Albers, 1966). The Klamath Mountains (which includes part of southern Oregon) have produced about 7 million oz of gold, most of it from placer deposits (Albers, 1966). Of the total production, about 9 percent is byproduct of massive-sulfide ores, 27 percent comes from lode deposits, and the remainder, 64 percent, is from placers (calculated from figures given by Albers, 1966, quoting Irwin, 1960). The California part of the Klamath Mountains has greatly dominated production (Hotz, 1971).

Most of the Cu, Zn, and Pb production is from massive-sulfide deposits in felsic volcanic rocks (Albers, 1981). Between 1862 and 1964, during which the bulk of production occurred, Shasta County, in the eastern Klamath Mountains produced about 335,000 tons of Cu. Other counties in the Klamaths, principally Siskiyou and Trinity produced another 21,000 tons (Kinkel and Kinkel, 1966). This represents 65 percent of California's total production during those years. Zinc is the most important other product from the massive-sulfide deposits. Production figures for that commodity are 75,000 tons from Shasta County, with very limited production from other counties (Goodwin, 1957).

Distribution of Mineral Deposits in the Klamath Mountains

Mineral deposits are not uniformly distributed throughout the province, but tend to be associated with particular terranes or groups of them. Lithologic, structural, and process factors, such as the effects of igneous intrusions in concentrating metals from their host rocks, probably control this distribution, but the factors are not obvious (fig. 4).

Lode Gold Deposits:

Gold was produced primarily from placer deposits after its discovery in 1848. The first lode mining in the Klamath Mountains occurred at the Washington Mine in French Gulch in 1852, but lode production lagged far behind that of placers until the 1880's. From then until World War I, at least as much gold was produced by lode mining as was by placer mining. Gold production dropped considerably in the 1920's (Albers, 1966). During the 1930's the bulk of the gold produced was by dredging operations, although quartz-lode mining activity continued. In 1942, gold production was stopped by President Roosevelt's executive order for the duration of World War II. It never again reached the levels of earlier times. Small scale placer mining and recreational placer mining still continue in the Klamath Mountains.

The placer deposits, some of which contain minor platinum and platinum group elements occur along the major rivers, particularly the Trinity, Klamath, Smith, and Clear Creek and their tributaries. Tertiary and Quaternary gravel deposits have also produced gold, as have beach deposits along the coast, in Del Norte and Humboldt Counties, in the Coast Ranges province (Hotz, 1971; Clark, 1970; Irwin, 1960). One of the largest placer mines in the U.S. occurs in the Klamath Mountains, at the La Grange mine (fig. 4), near Weaverville. It was active from 1851 through the 1940's and produced 390,000 oz of Au (Clark, 1970).

Lode gold deposits of the Klamath Mountains occur primarily in the eastern part of the province (figs. 4, 5) in terranes containing metavolcanic and metasedimentary rocks generated in island arcs. The most common lode gold deposits are mesothermal-type quartz or quartz-calcite veins similar to those along the Mother Lode to the southeast (Silberman and Danielson, 1991). Most of the rest of the gold came from volcanogenic massive-sulfide deposits as byproduct of Cu-Zn production. Gold-bearing skarn deposits are also present (Hotz, 1971). The gold-vein deposits vary in size from a few tens of ounces to quartz vein systems that produced more than 400,000 oz, such as at the Brown Bear Mine in the French Gulch district (Hotz, 1971; Albers, 1965). A small but unknown quantity of gold came from copper-bearing sulfide and quartz-sulfide veins and disseminations in ultra-mafic rocks from ophiolite complexes exposed in the western part of the Klamath Mountains and in the Trinity terrane, most of which occurs north of the Redding quadrangle (figs. 2, 4). There appears to be a spatial association of gold-bearing quartz veins with granitic plutons of a variety of ages. In most of the larger districts, hypabyssal intrusions, dikes, and (or) sills which are related to the plutons, are spatially associated with, and in many places host gold-bearing quartz veins (Silberman and Danielson, 1991; Hotz, 1971; Albers, 1965; Ferguson, 1914). Figure 4 shows, along with other deposits, the occurrence of quartz-vein deposits with production greater than $100,000 (5,000 oz) and the distribution of large plutons in the Klamath Mountains.

Similar island arc terranes occur further west in the Klamath Mountains, but no large vein deposits have yet been identified west of the Hayfork terranes in the Redding quadrangle, although numerous occurrences of small, gold-quartz vein systems abound, and considerable placer mining has occurred in that area. In fact, Au-placer deposits occur throughout the Klamath Mountains and are not restricted to areas where known lode mines occur (Irwin, 1960; Hotz, 1971).

Massive Sulfide and Other Base-Metal Deposits:

Massive-sulfide deposits were discovered in the Klamath Mountains in the 1860's but were initially worked for Au and Ag which were concentrated in their gossans. Unoxidized sulfides were first mined and direct smelted from the West Shasta district in 1896 for Cu with byproduct Au and Ag recovery. The Iron Mountain mine (then Mountain Copper mine) was the first to be developed. Zinc recovery started in 1918. Production from the copper mines peaked about 1917, at $11 million, and then declined sharply to virtually cease by 1920 (Albers, 1966). During the 1930's nearly 3 million tons of gossan were mined and processed at the Iron Mountain Mine for its Au content. Subsequent to that activity, pyrite was mined there for production of sulfuric acid from 1948 to 1962. The Iron Mountain Mine was continuously active for 65 years (Albers, 1966).

Cu, Zn, and Pb are found in the Klamath Mountains, mainly in massive-sulfide deposits of volcanogenic origin in metavolcanic rocks. Over 90 percent of the production came from deposits hosted in felsic metavolcanic rocks in the West and East Shasta copper-zinc districts in two island arcs, one Devonian-Mississippian and the other Permian-Triassic, of the Eastern Klamath terrane (Albers, 1981, 1966) in Shasta County (figs. 2, 4, 5). The sizes of massive-sulfide deposits vary from nonproductive concentrations of pyrite with some base-metal sulfides of a few tons to large masses that have produced well over 1 million pounds of copper. These massive-sulfide deposits have produced considerable byproduct Au and Ag. Massive-sulfide deposits also occur in other terranes of the Klamath Mountains. Two large deposits, with over 1 million pounds Cu production occur in northern Siskiyou County, in mafic metavolcanic rocks assigned to the Western Jurassic terrane (fig. 4). Many smaller ones occur throughout the region where metavolcanic rocks are present. Renewed interest in massive-sulfide deposits has been generated by recent increases in the prices of Cu, Zn, and Pb, and by the enrichment of gold in gossan zones frequently found associated with these deposits (Hotz, 1971).

Base metals, particularly Cu and Pb, were also produced from gold-bearing quartz veins in some districts, particularly in and near the ultramafic rocks of the Trinity terrane such as the Callahan district, where quartz veins had unusually high concentrations of sulfides (Hotz, 1971; Eric, 1948). Numerous prospects, and some production, of Cu, as copper sulfides in quartz veins, sulfide veins, and disseminations in serpentinite and diorite in areas of ultramafic rocks had been recorded. Many of these deposits also contain some Au. Although these deposits are common, they are not well known (Eric, 1948). The Horse Mountain district in the Western Jurassic terrane has several mineral deposits of this type (Silberman and Danielson, 1991).

Silver:

Silver is commonly produced as a byproduct of base metals in massive-sulfide deposits and also occurs with Au in quartz veins. The South Fork mining district, which is in granitic rock intruding the Eastern Klamath terrane in Shasta County, is the only occurrence we could find of significant Ag production, $1 million (Hotz, 1971), from a quartz vein system. The Silver Falls Mine, which was discovered in 1866, produced most of this before 1900 (Tucker, 1926; Albers, 1966). The veins contain little Au, but relatively high concentrations of base metals, particularly Zn (Silberman, and Danielson, 1991).

Pyrite:

Pyrite, mined for the production of sulfuric acid, has been produced chiefly as a byproduct from base-metal massive-sulfide deposits principally from the Iron Mountain mine (Albers, 1966).

Chromite and Nickel:

Chromite has been an important strategic commodity produced in the Klamath Mountains. Nearly all of it has been mined from podiform chromite masses in peridotite and serpentinite in the Josephine ophiolite of the Western Jurassic terrane and the Trinity terrane, with some production from similar rocks in other terranes (Albers, 1966, 1981). The distribution of ultramafic rocks in the Klamath Mountains is shown on figure 4. Podiform chromite bodies are usually small, containing from a few tons to greater than 10,000 tons with most of them in the range 15 to 150 tons (Rice, 1957). The ore bodies commonly occur in clusters, but even so, only 10 mines in the Klamaths have produced over 1,000 tons (Rice, 1957). Disseminated chromite ore bodies, although of lower grade, are usually larger. At Seiad Creek, in northern Siskiyou County (fig. 4), reserves of 266,000 tons of ore averaging 6 percent chromite have been drilled out (Rice, 1957). Scattered ultramafic bodies abound throughout the Klamath Mountains, and small chromite deposits are widely distributed (Albers, 1981).

Nickel is present in the Klamath Mountains, mainly as a weathering product of ultramafic rocks in Ni-bearing laterite (Albers, 1966, 1981; Rice, 1957). Occurrences are concentrated in the Josephine ophiolite of the Western Jurassic terrane in Del Norte County (Rice, 1957). An unpublished report in the Anaconda File at the Heritage Institute, University of Wyoming suggests evidence of as much as 70 million tons of mineable Ni-laterite with significant Co and Cr content in the region of ultramafic rock just south of the Oregon border in the vicinity of 124° W. long. and 42° N. lat. (Anaconda File, 1977). Few significant occurrences of chromite and none of nickel occur in the Redding quadrangle.

Manganese and Mercury:

These two commodities, although produced in the Klamath Mountains, are much more abundant in the Coast Ranges province. The manganese occurs in association with bedded chert of probable exhalative origin. It is found largely in melange terranes that contain oceanic crustal rocks, mostly in the Western Paleozoic and Triassic belt (Albers, 1981). The deposits are small in the Klamath Mountains, usually less than 1,000 tons (Davis, 1957).

Mercury is found scattered in a few small districts throughout the Klamath Mountains. The Altoona Mine, in the Trinity terrane is the only significant locality (fig. 4), having produced 34,000 flasks, mostly between 1871 and 1900 (Albers, 1966). The Hg occurs in diorite where it intrudes serpentinite (Albers, 1966). Other areas in the Klamaths have Hg prospects in schist where it is intruded by granitic rock, particularly northern Siskiyou County (Ransome and Kelley, 1939) or are associated with diorite dikes where they intrude ultramafic rocks (Albers, 1966, 1981). The few Hg prospects in the Redding quadrangle have not had significant production.

Mineral deposits of the Coast Ranges province

With the exception of Mn-chert deposits, called "Franciscan" type in some publications, the Coast Ranges province in the Redding quadrangle has not been significantly productive of mineral commodities. That is certainly not true for the province as a whole, as south of Redding significant numbers of large mineral deposits occur (Davis, 1966; fig. 6).

Historically, the most important mineral commodities of the Coast Ranges have been mercury and manganese in that order, but chromite, copper, silver, and gold have also been produced (Davis, 1966). The value of Hg produced, mostly from the Coast Ranges in California, was $198 million from 2.75 million flasks produced between 1850 and 1966 (Davis, 1966). That's more than the value of gold produced in the Klamath Mountains (Albers, 1966). Much of the Hg in the Coast Ranges occurs in silica-carbonate rock that is a hydrothermal alteration product of serpentinite. Much of it is found along the Coast Ranges thrust (Albers, 1981). Of great significance for current economic considerations is the occurrence of Au with Hg at several localities along this structure. The McLaughlin Au (fig. 1) mine was originally mined for Hg (Becker, 1888; Lehrman, 1986).

Most of the Coast Ranges manganese deposits are in chert in the Central terrane melange and are associated with basalt (Albers, 1981; Crerar and others, 1982). The Coast Ranges Mn deposits accounted for 60 percent of the 240,000 tons of domestic Mn produced between 1887 and 1954 (Davis, 1957).

Chromite has come entirely from ultramafic rocks, most of the deposits and all of the large ones are in the Coast Ranges Ophiolite (Albers, 1981; fig. 6). Cumulative production from chromite mines in the Coast Ranges is about 185,000 long tons (Davis, 1966).

Copper occurs mostly in small massive-sulfide deposits in metavolcanic-rocks in the Franciscan assemblage, in base-metal rich quartz veins in a variety of lithologies, and as disseminations and sulfide and quartz-sulfide veins in serpentinite (Eric, 1948). Some copper also has been produced from Au-bearing quartz veins in Tertiary volcanic rocks. Most of the copper deposits are gold bearing (Eric, 1948; California State Mining Bureau, 1915).

Gold and silver occur as components of the massive-sulfide deposits, within quartz veins in a variety of lithologies in the Franciscan assemblage and as Au-Ag-bearing quartz veins in Tertiary volcanic rocks. Gold occurs in some of the Hg deposits in silica-carbonate rocks and in volcanic rocks as well. Production data for Au and Ag in the Coast Ranges are not readily available, but the McLoughlin Au mine has reserves plus production of nearly 3 million oz (Lehrman, 1986), which about equals the lode production of the entire Klamath Mountains (Clark, 1970; Lehrman, 1986; California State Mining Bureau, 1915). Most of the Au-Ag and Cu deposits are south of the Redding quadrangle with the exception of the Island Mountain massive-sulfide deposit (fig. 4).

Distribution of Mineral Deposits in the Coast Ranges

Lode Gold deposits:

Gold occurs in quartz veins in a variety of lithologies in the Franciscan assemblage including sandstone, shale, glaucophane schist, and serpentinite (Clark, 1970; California State Mining Bureau, 1915). Gold, associated with pyrite, in diorites and schists occurs in Sonoma County (Clark, 1970). Epithermal quartz veins containing Au occur in the Tertiary volcanic rocks. The Palisade Mine in Lake County produced $2 million in Au and Ag along with some copper and lead (Rigby, 1986). All of the quartz-vein deposits that contain gold in the Coast Ranges are south of the Redding quadrangle. Except for beach placers, we were also unable to locate more than three Au-placer deposits in the region underlain by the Franciscan assemblage rocks of the Redding quadrangle. Gold also occurs in massive-sulfide deposits. The Island Mountain mine produced 8,600 oz of Au, along with Cu, and Ag (Stinson, 1957). Small massive-sulfide deposits occur in the Coast Ranges terranes, most of them south of the Redding quadrangle (Silberman and Hassemer, 1990; California State Mining Bureau, 1915).

The most significant gold discovery in the Coast Ranges was the McLaughlin mine in Napa County. Disseminated and stockwork vein gold occurs there along a strand of the Coast Ranges thrust. Gold-mineralization is hosted in the footwall lithologies of serpentinite and greenstone of the Coast Ranges ophiolite and graywacke. Mineralized hanging wall rocks are sandstones of the Great Valley sequence. Gold-mineralization also occurs in Tertiary volcanic rocks and sinter. The Au deposit is related to thermal spring activity and is associated with Hg mineralization. The discovery site of McLaughlin was at the old Manhattan Hg mine (Lehrman, 1986). Becker (1888) reported Au at the site. There are other occurrences of Au in silica-carbonate Hg deposits along the Coast Ranges thrust, but no significant Au production has yet occurred outside of McLaughlin (Rigby, 1986).

Copper deposits:

The only large copper deposit in the Coast Ranges in the western half of the Redding quadrangle is the massive sulfide at Island Mountain which produced more than 9 million pounds of Cu, 8,600 oz of Au, and 144,000 oz of Ag (Stinson, 1957). Koski and others (1992) have identified Island Mountain as a Besshi-type deposit occurring within a coherent slab of interlayered mudstone and graywacke bounded on one side by a band of melange. Other types of Cu deposits are similar to those described in the Klamath Mountains, including volcanic massive-sulfide deposits and veins and disseminations in serpentinite and diorite (Eric, 1948). Although no large Cu deposits, other than Island Mountain, have been found in the NW Coast Ranges small prospects, particularly the serpentinite hosted ones, are very common. They occur mostly south of the Redding quadrangle (Eric, 1948; California State Mining Bureau, 1915).

Mercury deposits:

Almost all of the productive Hg deposits in the Coast Ranges occur in silica-carbonate rock which is an alteration product of serpentinite. These probably represent the roots of ancient hot springs (Albers, 1981). The deposits are mostly close to, and in the footwall of the Coast Ranges thrust (figs. 1, 6). There are also Hg deposits such as Sulfur Banks, and the large Mayacamas district that appear to be related to active thermal springs (Albers, 1981).

Few, if any, Hg deposits occur north of lat. 39° N. The area where they occur to the south of this corresponds to the region where the Coast Ranges thrust is displaced by faults of the San Andreas system, and where Late Tertiary and Quaternary volcanic activity has taken place with associated thermal spring activity. The occurrence of Au in many of the deposits mentioned previously has generated exploration interest (Rigby, 1986), but, to date, no significant discoveries.

Manganese deposits:

Most of the Mn deposits occur in the Central terrane of the Franciscan assemblage (fig. 6). The Mn occurs as massive lenses of manganiferous chert, contained within thin bedded radiolarian chert. The chert typically overlies, concordantly, basalt or greenstone. Occasionally Cu and Fe sulfides occur in the basalt (Crerar and others, 1982). Barren massive chert lenses, and iron-rich chert lenses also occur in the same setting. The Mn chert contains 30 to 50 percent Mn, the Fe chert contains up to 60 percent Fe_2O_3, and less than 10 percent Mn (Crerar, 1982). These deposits are believed to be of submarine exhalative origin but have been modified by diagenetic and metamorphic processes (Crerar and others, 1982; Davis, 1957).

These Mn deposits are small, generally containing from a few tons to as much as 5,000 tons of ore (Davis 1957). Albers and Fraticelli (1984) suggest that the entire Central terrane of the Franciscan assemblage is prospective for Mn deposits of this type. The Central terrane melange has a higher proportion of volcanic rocks than the other Franciscan terranes (Crerar and others, 1982) and Mn-cherts are associated with greenstones.

MINERAL DEPOSITS IN THE WESTERN HALF OF THE REDDING QUADRANGLE

The geology of the Redding quadrangle was described in an earlier section. Figure 7 is a generalized geologic, or modified terrane map revised from the geologic map of the quadrangle (Fraticelli and others, 1987) and is the base for plotting all subsequent information. It would be helpful for the reader to be able to refer to a copy of this geologic map and the accompanying descriptive text (OFR 87-257). The text includes detailed lithological descriptions of units in the terranes and derivitive maps showing plutons, ultramafic rocks and the generalized terranes. Due to the complexity of the geologic map, we thought it best to plot information on this simplified version.

In the western half of the Redding quadrangle, the most common mineral deposits are Mn-cherts associated with mafic volcanic rock. The next most common type are mesothermal, gold- and silver-bearing quartz or quartz-carbonate veins, which occur mainly in the Klamath Mountains in graywacke-argillite and mafic gneiss and schist host rock. Some moderate size Au-vein deposits, which have produced up to about 30,000 oz of Au, occur in the Canyon Creek-East Fork district which is in the NE corner of the map.

Small massive-sulfide deposits containing Cu, Zn, and lesser amounts of Pb, Au, and Ag occur in volcanic rock and in sedimentary rock associated with the volcanics, mostly in the Klamath Mountains. Small deposits consisting of disseminated copper sulfides and copper-sulfide veins in serpentinite, and in dikes of diorite and felsic rocks which intrude the serpentinite, occur in both provinces, but are most common in areas of the Klamath Mountains that are underlain by ultramafic rocks. The deposits contain Au in addition to the Cu. The largest of these, at Horse Mountain, near the boundary of the Coast Ranges and Klamath Mountains, produced between 100,000 and 1,000,000 lbs of Cu and an unspecified amount of Au and Ag (Eric, 1948). The only other common, nonplacer deposits, are small podiform chromite bodies which occur in serpentinite in both provinces.

Placer deposits consisting of modern gravels in active streams, and older terrace gravels along the Trinity River drainage and its tributaries, are common in the Klamath Mountains. Some of them contain platinum and platinum group elements along with gold. There are a few poorly documented placer deposits in the Coast Ranges, but little data were found on them, other than their approximate locations.

DESCRIPTION OF THE CHARACTERISTICS OF THE PRINCIPAL MINERAL DEPOSITS OF THE WESTERN HALF OF THE REDDING QUADRANGLE

Map reference:
Mn mines and prospects, Map ____ (fig. 9).

Mineral deposit type and references:
Manganese-chert (Franciscan-type manganese).
1. Crerar and others, 1982.
2. Trask and others, 1943.
3. Davis, 1957.
4. Koski, 1986, model 24C, in Cox and Singer, 1986.

Principal commodity (commodities):
Mn

Host rocks association:

Massive manganiferous chert lenses spatially associated with greenstone or basalt in sequences of argillite-graywacke-basalt-chert. The massive lenses occur within sequences of thin bedded radiolarian chert that typically overlie the basalt or greenstone concordantly.

Principal terranes:
CT and YBT of the Coast Ranges.
RCT of the Klamath Mountains.
A few in WJT of the Klamath Mountains, and PPT of the Coast Ranges.

Grade, size, and significance:

Grades are typically 30 to 50 percent manganese. Deposits are generally small and contain from a few tons to less than 1,000 tons, usually in several chert lenses. Only three deposits in the quadrangle exceed 3,000 tons manganese ore. Chert lenses are a few centimeters to 30 m wide with an average of about 1 m. Strike length of lenses is centimeters to 300 m with an average of 15 m (1).

Although small, deposits were strategically important as an Mn source during World War I, World War II, and the Korean conflict.

Mineralogy:

Massive ore originally consisted of poorly crystalline or amorphous oxides, carbonates, and Mn-chert. Massive ore usually grades into disseminated ore at its margins. In northern California, diagenesis and metamorphism followed by supergene oxidation recrystallized the original minerals to a variety of silicates, carbonates, and oxides, including rhodochrosite, pyrolusite, haussmannite, rhodonite, bementite, and others. Several generations of quartz and manganese oxide veins occur within and below the massive chert lenses. The lenses are now usually steeply dipping due to the complex deformation of their syngenetic host rocks. The current near-surface mineralogy usually consists of oxides, due to weathering. The oxides are more desirable than the deeper silicate and carbonate primary ores. Underlying basalt is usually cut by sulfide and quartz-sulfide veins, and has disseminated sulfides (1, 2, 3).

Geochemical characteristics:

The deposits are enriched in Mn, Fe, Si, Cu, Ni, Zn, and Ba (1.). Analyzed samples from mines and prospects in the area have the above elements plus occasional enrichment of As, Co, V, and Hg to the maximum contents of 200 ppm As, 500 ppm Co, 2,000 ppm V, and 3.5 ppm Hg (Hassemer and others, 1992a, 1992b). Stream-sediment geochemistry of drainages in the vicinity of manganese mines and prospects show no consistent patterns in the quadrangle. In some terranes, drainages in the vicinity of deposits have anomalous contents of Co, Cr, Ni, Mn, Fe, Cu, and scheelite. In the Central terrane, scheelite in stream sediments is particularly well correlated with Mn occurrences in spite of the fact that no scheelite has been found in the deposits. Stream-sediment geochemistry is not a reliable exploration tool for these deposits in the western half of the Redding quadrangle. Areas with large amounts of mafic volcanic rock appear to be most prospective. Where geology is not detailed enough to indicate these areas, aeromagnetic anomalies appear to be useful, as they can indicate presence of unmapped mafic rock (Griscom and others, in press).

Large examples in quadrangle:

Blue Jay (No. 20), the largest mine in the quadrangle, produced 4,600 tons. Hale Creek (No. 44), produced 3,800 tons, Fort Seward (No. 5), produced 3,460 tons, and Fort Baker (No. 4), produced 650 tons (1, 3).

Map reference:

Gold Mines and Prospects. Map ____ (fig. 8).

Mineral deposit and references:
Mesothermal quartz and quartz-carbonate veins.
1. Hotz, 1971.
2. Silberman and Danielson, 1991.
3. Berger, 1986, model No. 36A, in Cox and Singer, 1986.

Principal commodity (commodities):
Au, Ag, lesser amounts of Cu, Zn, and Pb.

Host rock association:

Veins occur in a variety of host rocks, the most common in the western half of the Redding quadrangle are:

1. Hornblende schist and gneiss. The veins are frequently associated with quartz porphyry, aplite, and pegmatite dikes in the Canyon Creek-East Fork district. The Canyon Creek pluton is just north of the district.

2. Argillite and chert, near contact with underlying andesite volcanic unit in Hayfork and Harrison Gulch mining districts. Diabase, granite, and serpentinite intrusions occur near the veins at Harrison Gulch.

3. Hornblende diorite and argillite (?). Some are reported at diorite and serpentinite contact. The area is that of the small diorite-pyroxenite intrusion in the northern EHT.

4. Slate and porphyry.

5. Small vein occurrences in unspecified lithologies, probably slate and argillite. There are many small occurrences described only briefly in old California State Mining Bureau, Reports of the State Mineralogist, and in the more recent County Report 4, for Trinity County, by O'Brien (1965). Information is usually not comprehensive enough to classify the deposit, or specify the host rock type.

Descriptions of the veins in Canyon Creek-East Fork, Hayfork, and Harrison Gulch are given in References 1 and 2.

Principal terranes:
The numbers correspond to the varieties of host rock listed above.
1. CMT
2. WHT
3. EHT
4. WJT
5. EHT

Grade, size, and significance:

Most deposits in the quadrangle are small, producing considerably less than 5,000 oz. However, the available references, mostly from old reports of the California State Mining Bureau usually contain no data on grade and tonnage. The only documented large vein deposits occur in the Canyon Creek-East Fork mining district, and the Harrison Gulch district, but the large mine in that district, the Midas, one of the largest gold mines in the Klamath Mountains, is east of the boundary of the quadrangle. The western half of the Redding quadrangle accounts for only about 10 percent of the documentable lode Au production for the entire Redding quadrangle, which is estimated as between 2.1 and 2.8 million oz of Au (2). Many larger vein deposits hosted in argillite-graywacke, most of them associated with dikes and sills of granitic to intermediate composition, occur in the eastern half of the quadrangle.

Four of the five mines in the quadrangle with reported production greater than 5,000 oz (Ref. 1) are in the Canyon Creek-East Fork district, and had indicated gold production of between 10,000 and 30,000 oz each. The fifth mine, the Kelley, is in the Hayfork district and is estimated to have produced 5,000 oz (1). Quartz vein samples collected during this study from Canyon Creek-East Fork district had gold grades as high as 86 ppm (2.5 oz/ton) and Ag grades of as high as 27 ppm (0.8 oz/ton) (2). Vein width is generally less than 2 m (1, 2) and in our investigations of mines and prospects we rarely encountered vein widths greater than 1 m. Strike lengths of developed veins appear to not exceed 500 m. Physical descriptions of the vein deposits are rare and usually incomplete.

Mineralogy:

The quartz veins in general have somewhat variable amounts of pyrite, galena, sphalerite, chalcopyrite, arsenopyrite, tetrahedrite, and free gold. Generally, sulfide contents are less than 5 percent. Chalcopyrite, bornite, azurite, and malachite occur commonly in veins in the northern part of the EHT, which are more Cu rich than the others. This is usually true of veins hosted in mafic to ultramafic rocks. Arsenopyrite is most common in argillite-hosted veins. The districts and deposits differ in mineralogy from each other somewhat, although at least some of the minerals listed above occur in most of them. Few of the older references give much information on mineralogy of the smaller occurrences.

Geochemical characteristics:

Geochemistry of veins is different in different host rocks (2). Veins in hornblende gneiss have high Hg, As, Pb, and Zn contents and moderately elevated Ag and Cu. W contents are low, but consistently present at a few to about 30 ppm. Argillite-hosted veins have high As contents.

Stream-sediment geochemical signatures of gold-mineralized areas varies from district to district, as does the geochemistry. Orientation studies around Canyon Creek-East Fork district show that streams draining the mineralized areas have anomalous Au in minus 80-mesh stream sediment and (or) panned concentrates, as the most consistent signature. This is accompanied by anomalous Fe, Mn, V, Cu, and frequent Hg, Ag, W, and Co. One drainage has anomalous As. Around Hayfork, which is an argillite-hosted quartz vein district and quite small in production (about 5,000 oz, Ref. 1), Au and As anomalies occur in the stream sediments, with occasional Cu, Pb, Fe, and V. In the only other area where a few Au deposits occur together, the northern part of the EHT, where they are also associated with ultramafic Cu-Au deposits, Au, As, Mn, Ba, and W are anomalous in stream sediments, with occasionally anomalous Fe, V, Sb, Hg, Cu, and Pb. No single element appears to be a key indicator of gold mineralization, although Au is probably the most reliable. However, dilution and nugget effects complicate interpretation, and the size of a gold anomaly cannot be taken to indicate a greater degree of favorability, nor can its absence definitely rule out occurrence of gold-bearing veins. Probably, combined anomalies of Au, with As, Hg, W, and probably Cu would be good indications of mineralization in a drainage basin, but any of them should warrant follow-up. The other elements frequently associated with Au mines and prospects, Fe, Mn, V, Co, and Ba are most likely lithologically controlled, and are probably unrelated to the mineralized veins.

The association of gold deposits with plutons and hypabyssal intrusions is important (2), however, the map scale is inadequate to show areas of occurrence of dikes and sills which would be of prospective importance. Areas where unexposed plutons are likely present, indicated by aeromagnetic patterns, should be investigated, particularly where anomalous metals are present in the stream sediments.

Large examples in the quadrangle:
Alaska (No. 74), 30,000 oz gold.
Golden Crest (No. 73), 10,000 oz gold.
Enterprise-Lone Jack (No. 78), 18,000 oz gold.
North Star (No. 79), 10,000 oz gold.
Gold production figures from Ref. 1.

Map reference:
Cu mines and prospects, Map ____ (fig. 9).

Mineral deposit and references:
Massive sulfide hosted by volcanic or sedimentary rock.
1. Stinson, 1957.
2. O'Brien, 1965.
3. Koski and others, 1991.
4. Koski, 1981.
5. Singer, 1986, model 24A, in Cox and Singer, 1986.
6. Cox, 1986, model 24B, in Cox and Singer, 1986.

Principal commodity (commodities):
Cu, Zn, Fe, lesser amounts of Pb, Au, and Ag.

Host rocks association:

Host rocks are greenstone, graywacke, mudstone, slate, and schist. Large examples, north of Redding quadrangle, are found in greenstone-chlorite schist-slate-phyllite sequences in the WJT (4; Albers, 1966) at Grey Eagle and Blue

Ledge. Most of the western Redding quadrangle deposits are probably mafic volcanic hosted, or sediment hosted types (5, 6). The much larger deposits in the Eastern Klamath terrane of the eastern half of the Redding quadrangle are Kuroko types, associated with felsic volcanic rocks (Albers and Bain, 1985). The brief descriptions of the massive-sulfide deposits in the western Redding quadrangle come mostly from old reports of the California Mining Bureau, and in most cases are inadequate to classify them.

Principal terrane:
CT, WJT, WHT, EHT.

Grade, size, and significance:

With the exception of Island Mountain, all are very small, and because of this, are only sketchily described in the literature, with essentially no grade and tonnage estimated. Island Mountain produced 9,000,000 lbs of copper, 144,000 oz of Ag, and 8,600 oz of Au from 132,000 tons of ore, with an average grade of 3.3 percent copper, 2.2 g/t Au, and 37.4 g/t Ag (1, 2). The total reserve still present is estimated to be 390,000 tons (1, 2).

Mineralogy:

The Island Mountain deposit contains pyrrhotite, pyrite, chalcopyrite, sphalerite, arsenopyrite, and galena. Limited descriptive information for other small deposits in this area suggests many or all of these minerals are present, but the data are very sketchy.

Geochemical characteristics:

These deposits are characterized by high contents of Fe, Cu, Zn, Ba, Pb, As, Hg, and Sn. Au and Ag can also be elevated. The highest Au and Ag contents measured from massive-sulfide samples from the area in this work are 0.25 ppm and 100 ppm respectively from Island Mountain. Co, Cr, and Ni contents are high in mafic hosted examples of these deposits. Au tends to be concentrated in the gossans, which form from weathering of the massive sulfides.

Stream-sediment characteristics:

Orientation studies in drainages around the Kuroko massive-sulfide deposits of the East and West Shasta districts in eastern Redding quadrangle show anomalies in Ag, Cu, Zn, Pb, and Ba. Au was not analyzed. Only a few samples of stream sediment were analyzed near the small massive-sulfide deposits of west Redding quadrangle. Au, Ba, As, Zn, Pb, Cu, and Hg anomalies are present. Fe and Co anomalies are probably related to lithology and not mineralization. Unfortunately, no stream sediment samples were obtained from around Island Mountain.

Geochemistry of stream-sediment samples around areas of Au-bearing deposits of all types, massive sulfide, ultramafic and quartz-carbonate veins overlap, and areas geochemically anomalous in any combination of the elements is probably prospective for all types of the deposits.

Large example in quadrangle:
Island Mountain (1, 3).

Map reference:
Cu mines and prospects, Map ____ (fig. 9).

Mineral deposit and references:
Ultramafic hosted Cu-Au.
1. Laznicka, 1985 (p. 216-217; 220).
2. Laizure, 1925.
3. Knight, 1925, and other reports (Anaconda File).
4. O'Brien, 1965.

Principal commodity:
Cu, Au, lesser Cr, and possibly Ag.

Host rock association:
Host rocks are serpentinite, diorite, and plagiogranite. Mineralization is associated with dikes of diorite and felsic rock where they intrude serpentinite, and in places serpentinized pyroxenite. The environment and style of mineralization is common in parts of some ophiolite complexes such as Cyprus (1). Disseminated copper sulfides and copper sulfide veins, sometimes with quartz, are found in serpentinite where cut by dikes of diorite, and felsic rock. At Horse Mountain, the felsic dikes are fine-grained plagiogranites. The dikes are in places mineralized, and veins when present tend to occur along the dikes. At some places, such as Horse Mountain, there are chromite deposits near the Cu-Au occurrences, although the two types of mineralization are not obviously related.

Principal terrane:
WJT, particularly the Josephine ophiolite. Occurrences are also reported in the RCT, EHT/WHT, and one in the PPT (4). Although only one example was found in the Franciscan assemblage in the Redding quadrangle, these deposits are common in Franciscan terranes south of the Redding quadrangle.

Grade, size, and significance:
There is very little data available on size or grade. Eric (1948) suggests Cu production at Horse Mountain was between 100,000 and 1,000,000 lbs. Veins or zones of ore including stringers of high grade Cu-sulfides of up to 150 ft wide in adits are reported in this district (3). Dump samples of ore averaged 5.5 percent Cu and 0.23 oz/ton Au (2, 3). Au and Ag are reported present in assays (3). We could find no data for the other occurrences. See geochemical section.

Mineralogy:

Chalcopyrite, bornite, chalcocite, native copper, cuprite, malachite, chrysocolla. Primary ore is chalcopyrite.

Geochemical characteristics:

Mineralized rock samples collected at Horse Mountain had greater than 2 percent Cu, and 5 ppm Ag. We were unable to detect Au in our mineralized samples. High Ni and Cr were due to serpentinite lithology. Another prospect, the Murphy (4), had similar geochemistry, with 2 percent Cu, and 7 ppm Ag. Hg contents are sporadically high, greater than 1 ppm. As was not detected in samples from these mines.

Stream-sediment geochemical characteristics:

Drainages in the vicinity of Horse Mountain ultramafic Cu-Au mines and prospects are anomalous in Cu, Cr, Ni, Co, and Fe and have sporadic anomalies in Hg, Au, Zn, and Ba. Drainages around other areas containing these deposit types show Fe, Mn, Ni, Cr, and Co anomalies and sporadic pyrite (in C3), Cu and Hg. The chalcophile elements are probably lithologically related.

Drainages in the northern EHT in an area containing both ultramafic Cu-Au and vein Au deposits are anomalous in Au, As, Mn, Ba, W, and occasional Fe, V, Sb, Hg, Cu, and Pb.

Large example in quadrangle:

Horse Mountain (2, 3).

Map reference:

Placer gold mines and prospects, Map ___ (fig. 8).

Mineral deposit and references:

Gold and gold-PGE placers.

1. Diller, 1911.
2. Yeend, 1986, model 39A, in Cox and Singer, 1986.
3. O'Brien, 1965.
4. Averill, 1941.

Commodity:

Au, Pt, other platinum group metals.

Host rock association:

Gold occurs as native element, or electrum, sometimes with Pt alloys in beds of active streams and at or near the base of terrace gravels generally from 25 to 400 ft above the stream beds along the Trinity River and its tributaries. They also occur in older gravels (Miocene) that are generally tilted and preserved in down-faulted basins. The La Grange mine (fig. 4) just east of the quadrangle boundary is in such a setting, and at one time was one of the largest hydraulic mines in the country.

Principal terrane:

CMT, EHT, WHT, RCT, WJT along the Trinity River and its tributaries. Only three, poorly documented placers were found along other drainages in the Coast Ranges, in YBT and CT. Their locations are uncertain.

Grade, size, and significance:

Most of the large placer mines in the Klamath Mountains are in the eastern half of the Redding quadrangle. The La Grange mine, just east of the western part of Redding quadrangle, produced 390,000 oz of Au (Clark, 1970). Placer-gold production started in the early 1850's but adequate records were not kept until after 1880. The references listed have essentially no production data on the placers shown on the map. Most are small. Pt production was very minor in the region, being only about $120,000 worth (Albers, 1966) in the entire Klamath Mountains.

Mineralogy:

Native Au, or electrum, Pt-Fe alloys, Os-Ir alloys. The Pt-containing deposits tend to be in the western part of the Klamath Mountains where large areas of ultramafic rocks are exposed.

Geochemical characteristics:

Gold nuggets and smaller particles. In addition, Ref. 2 reports anomalous amounts of Ag, As, Hg, Sb, Cu, Fe, and S. The stream-sediment characteristic would be pannable gold.

Large example in quadrangle:

We could find no production figures and the summaries of placer mining in this part of California are quite old (Ref. 1). Most of the deposits are probably small, but some are very areally extensive, for example, the Bergin placer (No. P1) extends for 3 mi along the Trinity River (4). The extent of the area containing placers suggests that production was not insignificant. A significant amount of Au was probably recovered by dredging in Hayfork Valley (Irwin, written commun., 1992).

Map reference:

Chromite mines and prospects, Map ___ (fig. 9).

Mineral deposit and references:

Podiform chromite (Alpine-type chromite).

1. Rice, 1957.
2. Wells and Hawkes, 1965.
3. Albers, 1986, model 8A, in Cox and Singer, 1986.

Commodities:
Cr

Host rock association:

Ultramafic rock such as peridotite or dunite. Most commercial deposits are found in dunite, but most of this is serpentinized. Disseminated ore occurs in grains, nodules, stringers, and layers dispersed in the host rock. Massive ore has little or no interstitial gangue and usually occurs in podiform masses in the host rock and may have disseminated ore surrounding it. Tabular and lenticular shapes are most common (1, 2). The host rocks are strongly deformed and are usually parts of ophiolite sequences (3).

Principal terranes:
RCT, WJT, WHT, CT.

Grade, size, and significance:

The deposits in California and in this region generally are small. Massive ore bodies range in size from a few pounds to 20,000 tons. The largest deposit in the Klamath Mountains, which occurs in the Trinity ophiolite of the TT is about 15,000 tons (1). Few deposits in the western half of the Redding quadrangle are larger than a few hundred tons (2). Separate ore bodies tend to occur in clusters, and commonly appear to be faulted parts of a single body (1). Disseminated ore bodies can be large. Seiad Creek in northern Siskiyou County (fig. 4) contains a drilled-out reserve of 266,000 tons of ore containing 6 percent Cr (1). Massive ore contains greater than 80 percent chromite (2). Most ore was hand sorted, and analyses quoted in Ref. 2 indicate Cr_2O_3 contents of 40 to 50 percent with 10 to 15 percent Fe, but these data are from handcobbed concentrate from disseminated ore. Like the Mn-chert deposits of the Redding quadrangle, these small ore bodies had strategic significance, producing during World War I, II, and the Korean conflict.

Mineralogy:

Chromite, usually accompanied by magnetite, uvarovite, kammerite, and sometimes Ru-Os-Ir alloys (3).

Geochemistry:

Ore occurs in ultramafic rocks, and is of magmatic segregation origin (1, 2, 3). Geochemistry reflects that origin. The few analyses we have on chromite ores have high Cr, Fe, and Ni.

Geochemistry of stream sediments in drainages from areas containing chromite deposits in the RCT are anomalous in V, Cr, Ni, and Co, but these elements are primarily related to lithology of the region, which has large amounts of ultramafic and mafic rocks exposed. In other terranes where only occasional deposits are found, the stream-sediment relationship is not so marked. There is chromite in almost all C2 panned concentrates, sometimes greater than 1 percent. There is just too much mafic and ultramafic rock in the region for Cr to be a good geochemical indicator.

Large example in the quadrangle:

Most quite small. The largest examples are: Turner Group (No. 18), greater than 1,000 tons; Vance Group (No. 59), 480 tons; Phillpot (No. 53), 268 tons; and Yellow Pine (No. 63), 206 tons (2).

STREAM-SEDIMENT GEOCHEMISTRY

During the course of field investigations in the western part of the Redding quadrangle, 774 samples of stream sediment were collected, mostly from first or second order streams (fig. 10). Three-hundred-sixty-three panned concentrates were prepared from splits of these samples. All stream-sediment samples were sieved to -80 mesh and the fine fraction analyzed by semiquantitative, 6-step E-spec for 30 elements, supplemented by AA analyses for Au, As, Sb, Zn, and Hg (Smith and others, 1990, 1991). Weakly magnetic (C2) and nonmagnetic (C3) fractions of the panned concentrate were analyzed by E-spec (Smith and others, 1990, 1991) and C3 was examined for mineralogy by R.B. Tripp. Details of sampling, analytical procedures, analytical data, and sample locations, including the outlines of the drainages sampled at scale of 1:100,000 can be found in Smith and others (1990) for the Hayfork 1:100,000-scale quadrangle, which is the northern half of figure 10, and in Smith and others (1991) for the Garberville 1:100,000-scale quadrangle, which is the southern half of figure 10.

A statistical analysis for selected elements (Au, Ag, As, Sb, Hg, Zn, Cu, Pb, Ba, Fe, Mn, Co, Cr, V, Ni, and Sn) was done and percentiles and histograms of the data were plotted. Examination of the histograms of the element's distribution for natural breaks in the distribution patterns led to definition of anomalous concentrations of these elements greater than about the 75th and 90th percentiles for each. Drainage anomaly maps were plotted at these percentiles for each element and compared with the geologic map and maps showing the distribution of the most common types of mineral deposits in the quadrangle. It was found that the drainage maps plotted at the approximate 75th percentile showed good correlations with various geologic features such as plutons, thrust faults, ore deposits, etc. Drainage maps showing distribution of selected ore minerals visible in C3 panned concentrates (sulfides, scheelite, visible gold, cinnabar) were plotted and compared in similar fashion. Although this method of analysis of stream-sediment data is admittedly non-rigorous, it appears to be adequate for this assessment as it successfully identified areas of occurrence of certain mineral deposits and was able to facilitate identification of areas favorable for occurrence of undiscovered deposits. A more thorough analysis of the data will be presented elsewhere. We will briefly describe distribution of drainages containing anomalous amounts of selected elements by our criteria below.

Anomalous areas, shown as drainages or clusters of drainages surrounded by the same pattern for the elements Fe, Co, Cr, and Ni appear to be related to lithology (fig. 11). They appear to be concentrated in areas underlain by large amounts of mafic and ultramafic rocks, such as RCT, northern WJT, where Horse Mountain and its ultramafic host rocks occur, and geophysical data suggests the occurrence of widespread subsurface serpentinite (Griscom and others, in press) and the northern EHT, NFT boundary region which has a large amount of serpentinite and mafic rocks. Areas of high concentrations of these elements in the CT correspond to geophysical signatures of moderate to high magnetic anomaly which are indicative of the presence of mafic volcanic rocks or serpentinite in the melange—only some of which is mapped (Griscom and others, in press). V has about the same distribution as Fe, Co, Cr, and Ni.

Figure 12 shows distribution of drainage areas anomalous in Ba, Mn, and Sn. Ba is widespread, and not particularly concentrated in any particular terrane. Except along parts of the Ironside Mountain batholith it is most common in areas underlain mostly by sedimentary rock. Mn is strongly concentrated in the RCT which has a high proportion of mafic volcanic rock, in the WHT where volcanic rocks are common, and in the CMT which has a large component of metamorphosed mafic to intermediate volcanic rocks. Mn distribution tends to follow that of Fe, Cr, Ni, and Co, but it is not as widespread in the areas of ultramafic rock except in the southern RCT. Very little Mn occurs in the Coast Ranges, in spite of the occurrence of large numbers of Mn-chert deposits in the CT and YBT. Sn is almost entirely in the Klamath Mountains. It overlaps but is more restricted in distribution than Ba. Most of the Sn anomalous drainages are in RCT or are intersected by thrust faults along several of the terrane boundaries.

The distribution of drainages with anomalous Cu, Zn, and Pb is shown on figure 13. Most of the Cu anomalous drainages are in the Klamath Mountains, but controls on Cu distribution are not obvious. Some of it appears to be related to the presence of ultramafic rocks and mafic to intermediate plutons, or their geophysical signatures, as in the northern WJT, WHT, EHT-NFT boundary area and the southern part of the RCT. Structurally complex areas with thrust faults appear to have associated Cu anomalies, as along the central part of the boundary between EHT and WHT. In the Coast Ranges, most of the Cu anomalies are in the PPT along the ridge of South Fork Mountain and the thrust boundary between PPT and YBT, which appears to be a geochemically very enriched structure. A large cluster of drainages with anomalous Cu also occurs in the northeastern CT, and overlaps the PPT, WJT, and RCT where numerous thrust faults are exposed and close together. Smaller areas of anomalous Cu drainages occur elsewhere in the CT and YBT, usually associated with broader Pb and Zn anomalies.

Zn and Pb are more commonly anomalous in drainages in the Coast Ranges than the Klamath Mountains. Where they occur in the Klamath Mountains, they are generally associated with Cu anomalous drainages but are not as widespread. Pb appears to be spatially associated with plutons in the northern Klamath terranes, with Zn being more areally restricted than the Pb, and more characteristic of areas with complex structures. Both Pb and Zn are common in drainages along South Fork Mountain (PPT), and the PPT/YBT boundary thrust, as is Cu. A large cluster of Pb-anomalous drainages, accompanied by some with Zn, occurs in the southeastern YBT where the geologic map (Fraticelli and others, 1987) shows a large amount of thrust faulting. Part of this anomaly cluster extends across the YBT/PPT border and into the RCT as well. Many of the Pb anomalies in CT are associated with the Ctss, sandstone unit (Fraticelli and others, 1987) and they also tend to occur in the sandstone-dominated YT and COST terranes of the Coast Ranges as well. The PPT outlier in CT has Pb, Zn, and some Cu anomalies associated with it. The Pb-Zn cluster just north of the PPT outlier occurs over a geophysical "dome," (based on aeromagnetic data), which is believed to indicate the presence of a subsurface pluton (Griscom and others, in press).

Cu anomalies tend to be more consistently associated with ultramafic Cu-Au deposits than with VMS examples, but there are so few of the latter deposits in the western part of the Redding quadrangles, and they are so sparsely distributed that sampling is inadequate to be definitive. In the eastern part of the Redding quadrangle, Cu, Zn, and Pb are anomalous in drainages in the East and West Shasta Cu-Zn districts, which have large VMS deposits (Silberman and others, 1991). Cu anomalies also occur in some drainages near Au-vein deposits in the Canyon Creek-East Fork, and Hayfork gold-vein districts. Pb and Zn anomalous drainages occur in areas with VMS and ultramafic Cu-Au deposits, and Pb anomalies occur in some drainages near the Hayfork deposits, and in the northern EHT area, which contains both Au-vein and ultramafic Cu-Au deposits.

The thrust boundary between the PPT and YBT has Pb-Zn and Cu anomalies associated with it from its eastern intersection with the quadrangle boundary to about latitude 40°40' N. This segment of the terrane boundary has other anomalies, including Hg, As, and the occurrence of pyrite along it as well.

Figure 14 shows the distribution of drainages containing visible pyrite and (or) other sulfides in the nonmagnetic fraction of the panned concentrates. There is no overall lithological control of sulfide distribution, although many sulfide anomalous drainages and clusters occur in areas of complex structure, thrust faults for example, or near intrusive rocks, or their geophysical signatures as in the EHT and southern RCT. The consistently highest sulfide concentrations (greater than 1 percent) were along South Fork Mountain, the thrust boundary between the YBT and PPT, around and within the PPT outlier in the CT, and in the southern RCT, where there is a significant plutonic component. Pyrite occurs in the CT, mainly in the southern part, where the volcanic rock component is greatest. Many lithologies in the Klamath Mountains and the Coast Ranges contain sulfides, such as black shales, greenstones, etc., so there is no lack of sources for the sulfides. There is no consistent association between the occurrence of pyrite in stream sediments and mineral deposits of any kind.

The distribution of drainages or clusters of them with visible scheelite in the C3 panned concentrate fraction, or detectable within the stream sediments or panned concentrates is shown on figure 15. We thought that scheelite might have some importance because of its widespread occurrence in gold-bearing quartz veins and its common association with Sb and Hg in black shale-argillite sequences which contain mafic and ultramafic bodies in highly tectonized terranes (Laznicka, 1985). The geochemical assemblage of the elements W, Sb, and Hg is present in the western half of the Redding quadrangle, mainly in the CT, but no known mineral deposits of any of them are present.

Many of the scheelite-W bearing drainages are in CT or the PPT outlier. There are concentrations in the northern EHT where geophysical data suggest a large subsurface plutonic mass (Griscom and others, in press), and in areas of thrust faulting along other Klamath Mountains terrane boundaries in the northern part of the map area. Anomalous drainages also occur in the CMT where the gold-bearing veins of the Canyon Creek-East Fork district have moderate (up to 35 ppm) but consistently present W. Scheelite-W anomalies correspond to the occurrence of some known mineral deposits, the gold-bearing veins mentioned above, and the small area in the northern EHT where a few Au and ultramafic Cu-Au deposits occur together. That association, and the occurrence of scheelite in some gold-bearing veins in the eastern half of the Redding quadrangle (Lydon and O'Brien, 1974) marks it as noteworthy, and areas of scheelite occurrence, particularly where associated with Au anomalies, warrant consideration.

Scheelite also occurs in a few drainages within areas of Mn-chert deposits in RCT and in many drainages and clusters in the areas of Mn-chert deposit concentrations in CT. However, no W is reported in those deposits, and we have found no detectable W in the Mn-ores or host rocks analyzed in our study (Hassemer and others, 1992a, 1992b).

Figure 16 shows the distribution of drainages containing As and Sb anomalies. There is some overlap, but in general, the elements do not occur together. Most Sb-anomalous drainages are in the CT and YBT where there is overlap with the occurrence of scheelite-W. Most As is in the YBT and PPT, and along the thrust fault boundary of these terranes. Clusters of As-anomalous drainages also occur in northern WJT, EHT, and NFT. There is a spatial association of these anomalies with plutons or their geophysical signatures. Other As anomalies occur along thrust faults at terrane or subterrane boundaries. As, which is a component of argillite hosted Au-vein deposits and VMS deposits occurs in drainages near the Hayfork gold-vein deposits, and in the vicinity of the Au-vein and ultramafic Cu-Au deposits in the northern EHT, and near the few VMS deposits in the quadrangle.

Hg-anomalous drainages are shown on figure 17. There is a considerable overlap with scheelite and Sb occurrences in the CT and other areas of the quadrangle as well. We think the significance of Hg distribution is that strongly anomalous Hg, greater than 0.12 ppm, or the 91st percentile, is associated with most of the defined Au and Cu deposits of the area. This is particularly true of Canyon Creek-East Fork, Hayfork, Horse Mountain, and the northern EHT area, but Hg anomalies occur around most of the few VMS deposits as well. However, there is the possibility that some anomalies could be the result of Hg contamination in some of the gold mining areas.

The distribution of Au- and Ag-bearing drainages is shown on figure 18. Many of them are in the CMT, where there is a strong association with the Au-bearing vein deposits of the Canyon Creek-East Fork district, and the EHT. Those in northern EHT are near small Au-bearing quartz-vein deposits and small ultramafic Cu-Au deposits near a diorite-pyroxenite pluton. The other Au-bearing drainages have no known deposits associated with them, but are generally proximal to thrusts or other structural complexities, or are along trends of geôphysical indications of subsurface plutons. In the EHT, this really extends the area of occurrence of the small mafic to intermediate plutons shown on the map into a much larger, mostly subsurface body (Griscom and others, in press). One of the streams draining the Horse Mountain area has anomalous Au, as do the drainages around Hayfork Au-vein mines. Au also occurs in drainages in the vicinity of other Cu prospects of both VMS and ultramafic types.

There are many Au-anomalous drainages and clusters. We consider Au to be the best indicator of the presence of Au deposits based on the consistency of association of drainage anomalies and gold mines in the western half of the Redding quadrangle, and also in the larger districts in the eastern half (Silberman and others, 1991). Many of the drainages and clusters containing Au also have anomalous concentrations of other elements associated with Au in vein deposits such as Hg, As, and scheelite-W, and in ultramafic Cu-Au and VMS deposits such as Cu. Figure 19 shows Au, Ag, As, and Hg anomalies plotted together. We would rank drainages with multiple element anomalies higher in their potential to contain an Au deposit, but we consider any Au anomaly to be worthy of further investigation. In the next section of this report, we will review the element associations in the deposits we described here, and their stream-sediment geochemical signatures. Following that, we will attempt to indicate potential occurrence areas, based on geologic, geochemical, and geophysical data summarized so far in the report.

The procedure for following up our suggestions is simplified by the available drainage maps and geochemical data published recently by Smith and others (1990, 1991). Individual drainages of interest can be identified from the small-scale drainage map (fig. 10). The actual geochemical data for -80-mesh stream sediment, and panned concentrates C2 and C3 for this drainage, can be looked up in those publications. The drainage outlines, at 1:100,000 are part of the location maps of these references, and will serve to precisely locate the drainage, which then can be examined in the field for the source of the anomaly of interest. Our mineral potential maps (figs. 21-24) will not usually identify individual drainages, unless these happen to occur separated from other anomalous ones.

ASSESSMENT OF POTENTIAL FOR OCCURRENCE OF MINERAL DEPOSITS

Summary of geochemical characteristics

Table 1 lists the geochemical characteristics of the main deposit types and stream-sediment anomalies that are associated with them. These data were derived from examples within the quadrangle.

Table 1. Geochemical characteristics of the main types of lode deposits in the western half of the Redding quadrangle

Deposit type	Commodity	Elements enriched in deposit	Elements anomalous in stream sediment
Podiform chromite	Cr	Fe, Cr, Ni	V, Cr, Ni, and Co, but these may be related to lithology.
Mn-chert	Mn	Mn, Fe, Si, Cu, Ni, Zn, Ba, As, Co, Hg, and V	Not consistent. In some terranes Co, Cr, Ni, Mn, Fe, Cu, and scheelite are present.
Mesothermal quartz vein	Au, Ag, Cu, Pb, Zn	Variable, depends on host rock. Usually As, Ag, Hg, some Pb, Zn, Cu, and W.	Variable, may depend on host rock. Au, most important. Hg, As, Cu, Pb, and W, sometimes Ag.
VMS[1] SMS[2]	Cu, Zn, Fe, Au, Ag	Fe, Cu, Zn, Ba, Pb, As, Hg, Sn. Ag and Au can be high. Au can be enriched in gossan.	Cu, Zn, Pb, As, Ag, Au, Hg, and Ba.
Ultramafic Au-Cu	Cu, Au Ag	Cu, Ag, Au, Hg, and metals of mafic rocks—Cr, Ni, Co, Fe.	Cu, Hg, Au, Zn, Pb.

[1]VMS = volcanic-hosted massive sulfide.
[2]SMS = sedimentary-hosted massive sulfide.

There is considerable overlap in the geochemistry of deposits and in the stream sediments that occur in their vicinity for Mn-chert, Au-vein, VMS and ultramafic Cu-Au types. It appears likely that Au anomalies, associated with As and Hg, particularly in argillite-graywacke regions are a good indication of the presence of Au-veins. However, VMS and ultramafic Cu-Au deposits are associated with anomalies in these elements also. In like manner, anomalies of Cu with Zn and Pb appear to be favorable for the occurrence of VMS deposits, yet, Au, Hg, and As, which are present in the deposits, can also occur in drainages near them, as indicated by orientation studies in eastern Redding where larger examples of these deposits occur, as well as in this study area.

We do not believe, at the present stage of interpretation of the geochemical data, that metal anomalies can indicate which type of deposit may exist in a drainage. Rather, we suggest that geochemical anomalies involving the elements Au, Ag, As, Hg, Cu, Pb, Zn, and combinations of them, are suggestive of some type of mineralization (not necessarily an ore deposit) in an anomalous drainage, but are not with certainty diagnostic of the type. The rock types in the drainage may serve to limit the possibilities, but the western half of the Redding quadrangle is mapped only in reconnaissance, and most of the geologic units in the various terranes contain a variety of rock types (Fraticelli and others, 1987).

Because there are so few mineral deposits in this region, other than the generally small podiform chromite and Mn-cherts, which have essentially nonspecific stream-sediment geochemistry, it is difficult to produce a realistic assessment of potential for occurrence of specific deposit types, at least from geochemistry. We have tried to indicate the elements or groups of them that occur in the different deposit types, but there is too much overlap for this to be completely diagnostic. Certain elements, such as Ba which is frequently associated with VMS deposits, and perhaps Co, Cr, and Ni, in more mafic hosted VMS deposits, and ultramafic Cu-Au deposits, which might be indicative of deposit type, are just too widely distributed in the region due to the lithology of the terranes to be diagnostic. The geochemistry is certainly helpful in indicating areas that may contain deposits, and we have developed a scheme to show our interpretation, but we caution the reader to bear in mind that regions we consider favorable for certain deposit types, are most probably also favorable for a variety of others.

There are 52 drainages or drainage clusters that are anomalous in Au in the western half of the Redding quadrangle (fig. 20). Of these, only six are associated with known gold-deposits (figs. 8, 20). That leaves a lot of prospective area to evaluate. It is instructive to examine the elemental associations in those Au-anomalous drainages that are related to known deposits (table 2).

The associations are not consistent, although perhaps of importance, not one of these drainages or drainage clusters is a single element anomaly.
There are not enough VMS deposits in western Redding to make the same kind of comparison. Areas prospective for Au-vein deposits are considered prospective for VMS Cu-Zn deposits and vice versa. The general distribution of

both types of deposits in the Klamath Mountains of California certainly argues for this interpretation (Silberman and Hassemer, 1990).

Table 2. Association of Au with other elements in anomalous drainages in the western half of the Redding quadrangle. [Anomaly numbers refer to those on figure 20. CANCEF refers to Canyon Creek-East Fork]

Anomaly no.	District or area	Geochemical association
51	Hayfork (Au)	Au + Hg + As + Cu
47	CANCEF (Au)	Au + Ag + Sch
46	CANCEF (Au)	Au + As + Cu + Ag + Sch[1]
40	CANCEF (Au)	Au + Ag + Cu + Sch
30	Northern EHT (Cu and Au)	Au + Hg + As + Cu + Pb + Zn + Sch
3	Horse Mountain (Cu and Au)	Au + Hg + As + Cu + Pb

[1]Sch = scheelite in C3, or anomalous W in C3, or -80-mesh stream sediment.

Our scheme for indicating the potential for occurrence of Au, Cu, Mn, and chromite deposits is modified slightly from that used for the preliminary mineral resource assessment of Northern Spotted Owl habitats in northern California (Silberman and Hassemer, 1990). We use a three level, *qualitative* assessment, based on the following criteria:

Level 1. Highest probability for the occurrence of deposits is based on the actual occurrence of mines and prospects in the area. Where studied, these areas also usually have favorable geochemical anomalies in the stream sediments from drainages within them, at least for Au and Cu deposits.

Level 2. Next highest probability for the occurrence of deposits is based on drainage anomalies of elements that we believe are indicative of those deposit types, and also the presence of favorable geologic conditions, such as lithologies, structures, etc. Favorable geochemistry for Au-vein deposits, for example, would be the occurrence of drainage anomalies of Au, which is the best indicator for Au-mineralization, but as we discussed earlier, the more elements associated with Au, the better we view the prospects of the drainage. The same holds for VMS Cu-Zn and ultramafic Cu-Au deposits. In order to simplify the maps, we consider any area with anomalous Au in the stream sediments to have level-2 probability for Au-vein deposits. In like manner, we assume any area that has anomalous Cu to have level-2 probability for VMS/SMS and (or) ultramafic Cu-Au deposits. There are few lithologies in west Redding that would be unfavorable for the occurrence of at least some of the deposit types discussed above. The geochemical criteria used for each deposit type are on the legends of the deposit "hot dog" maps (figs. 21-24; actually, the hot dogs look more like measels or amoebas). Areas with level-2 probability can be defined only where geochemical data are available. Areas without stream-sediment samples cannot be evaluated for this level and may have good potential at this level. Refer to figure 10.

Level 3. This probability is based on the occurrence of favorable lithology, without geochemical anomalies, or in areas without geochemical coverage. For Au-vein deposits, the presence of plutons or the geophysical indication of their subsurface occurrence would be considered to have level-3 probability, due to the spatial association of these deposits and plutons (Silberman and Danielson, 1991).

The basic data for production of the level-2 potential areas are the drainage anomaly maps, particularly figures 3, 6, 7, 8, 19, and 20. The areas are generalized on the hot dog maps. For more detail, refer to the source maps.

Au-vein assessment

Areas with level-1 potential for gold (fig. 21) are small, and reflect the occurrence of mines and prospects, mostly in CMT and WHT, which have some defined mining districts (fig. 8). There are scattered occurrences or groups of mines and prospects in the EHT, RCT, and WHT. Areas with level-2 potential are based on anomalous drainages as discussed above and suggest large permissive tracts for the occurrence of Au-vein deposits. The EHT is particularly favorable because it contains a high proportion of argillite-graywacke, and granitic plutons or their geophysical indications. The multi-element nature of many of the Au-anomalous drainages in this terrane (fig. 20) is another favorable indication. There are eight anomalies or clusters along the South Fork Mountain fault, the boundary thrust between the Coast Ranges and Klamath Mountains (a geologic situation not dissimilar to that at the McLoughlin mine), and seven of them are multi-element, fig. 20).

Although there are no known Au-deposits in the Coast Ranges in western Redding, there are 21 Au-anomalous drainages and clusters, some of them quite large, and most of them (16) are multi-element (figs. 19, 20). Many of these are surrounded by quite large areas of As and (or) Hg anomalous drainages (fig. 19), which we suggest is also favorable for occurrence of Au-vein deposits. The rocks in CT, YBT, etc., contain many varieties that are favorable host rocks, such as argillite, graywacke, greenstone, or their metamorphosed equivalents.

Areas with level-2 potential areas could be expanded to include the concentrations of placer-Au deposits shown on figure 8. Many placers occur where there are lode mines, but their distribution is much more widespread than that of known mines. We have added the locations of isolated placers to the map (fig. 21).

Areas with level-3 potential reflect the relationship between the gold-quartz vein deposits and plutons. The scale of the map is inadequate to show all hypabyssal intrusions that occur in all of the terranes. There are probably many additional areas that are prospective on this basis, that will be identified as detailed mapping proceeds.

Figure 19 shows that most Au-anomalous drainages are associated with As and (or) Hg, if not in the same drainage, then in adjacent or nearby ones. As, and (or) Hg anomalous drainages, even in the absence of Au, may be prospective for Au-vein deposits, and the "amoebas" of figure 21 might be expanded to include these areas. This method was used for assessment of Spotted Owl habitats (Silberman and Hassemer, 1990), but we prefer to be conservative here, and have indicated as level-2, only Au-anomalous drainages.

VMS Cu-Zn and ultramafic Cu-Au assessment

Areas with level-1 potential are very small and consist mostly of ultramafic Cu-Au deposits and quartz veins that have copper sulfides; probably most of them were primarily Au producers or prospects. We say this tentatively, because there is very little data for them. Of the former, only Horse Mountain produced much Cu (Eric, 1948). Only a few VMS deposits occur, but they include Island Mountain, the largest Cu, Ag, Au producer in the Coast Ranges in this part of California.

Areas with level-2 potential are generalized from the widespread Cu-anomalous drainages and clusters in the Klamath Mountains discussed earlier. There are far fewer of these in the Coast Ranges, except in the CT and PPT. If Pb- and Zn-anomalous drainages were included on the map (fig. 13), then the areas of potential occurrence in the Coast Ranges, in YBT and CT, would be much enlarged. Many of the Cu anomalies overlap Au, particularly in the Klamath Mountains, but also in the Coast Ranges (fig. 20). Many of these areas, based on the occurrence of ultramafic rocks, are prospective for ultramafic Cu-Au. In the Klamath Mountains, Pb- and Zn-anomalous drainages are more restricted than those for Cu. Usually, drainages with multiple element anomalies, such as Cu+Zn+Pb would be considered more prospective than those with only Cu. Geochemical orientation studies in the East and West Shasta districts (Hassemer, 1983; Silberman and others, in press) confirm this. However, the massive-sulfide deposits in those areas are hosted in felsic volcanic rocks. In the western half of the Redding quadrangle, massive-sulfide bodies are hosted in mafic volcanic rocks or argillite-graywacke sedimentary rocks. There are so few of them (fig. 9) that the assemblages of anomalous elements (table 1) must be considered tentative. Cu does seem to be the most consistent element of the assemblage present. Therefore, we have specified the definition of areas with level-2 probability as any drainage cluster with anomalous Cu. Most likely, the occurrence of other elements with Cu, such as Pb, Zn, Hg, Ag, and Au would enhance the probability of the presence of a massive-sulfide deposit within a drainage.

South Fork Mountain and the thrust boundary between the YBT and PPT, which is just west of and structurally beneath the South Fork Mountain fault, has a large cluster of Cu-anomalous drainages. Many drainages are also anomalous in Pb, Zn, As, and Hg. This thrust fault and its hanging wall, mostly the South Fork Mountain schist, between about 40°15' N., 123°15' W. and just north of 40°30' N. and 123°30' W. is enriched in many of the elements characteristic of both Cu and Au deposits of a variety of types. While no mineralization is known to occur within this unit or along the structure, our field crews did find boulders of massive sulfide in a landslide block near Ruth Reservoir (GMS on fig. 22). The source was never located. Lithologic descriptions of the South Fork Mountain schist, which underlies most of South Fork Mountain, are not detailed enough to suggest sources of these anomalies. The South Fork Mountain schist and its bounding footwall structure need to be evaluated for occurrence of Cu and (or) Au deposits.

We consider areas with a large volcanic component such as WHT, RCT, NFT, the PPT outlier, and CT to be favorable for occurrence of VMS Cu-Zn deposits, and areas which have ultramafic rocks as favorable for ultramafic Cu-Au occurrences, particularly where Cu and Au anomalies occur together. We would include those terranes in total as having level-3 potential, which is admittedly not very helpful. The CT has a considerable volcanic component (Crerar and others, 1982), and geophysical data (Griscom and others, in press) suggests it is more extensive than currently indicated on the geologic map (Fraticelli and others, 1987). Large felsic volcanic sequences like those which host the Kuroko-type VMS deposits in eastern Redding are lacking in the western part of the quadrangle, so that we consider potential for the occurrence of those systems minimal. There are large sediment-hosted (Besshi-type) Fe-Cu-Zn deposits hosted in lithologies similar to those in the western half of the Redding quadrangle in the WJT, in the Weed quadrangle to the north, near the Oregon border (Albers, 1966). This suggests that these lithologies in the western half of the Redding quadrangle are prospective for these deposits, and Cu ± Zn ± Pb anomalies should be investigated. The occurrence of the large Island Mountain deposit in the CT suggests that Cu ± Zn ± Pb anomalies in the Franciscan assemblage rocks of the Coast Ranges are also prospective for this type of deposit.

Mn-chert assessment

Areas with level-1 potential include the areas of occurrence of the Mn-chert deposits, which are mostly concentrated in RCT, YBT, and CT (fig. 23). Areas with level-2 potential in the CT are based on the empirical relationship noted earlier of correlation between drainages that contained scheelite and the occurrence of Mn-chert deposits. The correlation is not so marked in other terranes where Mn deposits occur. We suggest that the Mn deposits be examined carefully for scheelite by U.V. Our geochemical data have too high a detection limit (50 ppm) to rule out its presence. The association of Mn and W in subaerial hot spring deposits, such as that at Golconda, Nevada, is well known, but to our knowledge, it has not been documented in submarine deposits such as those in the western half of the Redding quadrangle. For RCT, Mn-anomalous drainages occur in the area that contains Mn deposits in the southern part of the terrane, but the association is not as well developed elsewhere. In CT, areas with Mn-anomalous drainages are smaller than the areas of occurrence of the deposits. Our level-2 potential area is nonrigorous. It is based on an inconsistent empirical relationship that works well in a specific terrane and needs further investigation.

Tracts with level-3 potential were defined on the basis of including terranes with a significant mafic volcanic component, including CT, where geophysical data suggest that much more of these rocks are present than shown on the geologic map (Griscom and others, in press). We did include NFT, which has favorable rocks but lacks Mn-chert deposits within it, for reasons that are not apparent (Irwin, 1972). Albers and Fraticelli (1984) suggested, on the basis of geology and occurrences of Mn-chert deposits, that the CT appears particularly favorable for additional deposits.

Podiform chromite assessment

Tracts with level-1 potential include the areas of occurrence of the deposits (fig. 24), mostly in the RCT, with a few in WJT, WHT, CT, and PPT. Level-2 potential is not defined due to the lack of consistent relationship between geochemistry of drainages and occurrence of deposits for reasons discussed earlier.

Tracts with level-3 potential include those areas with a large ultramafic rock component, such as the entire RCT, and parts of other terranes where these rocks are exposed, or where geophysical data suggest they are present. In some cases, level-3 potential areas are enlarged from the outcrop areas shown on the map based on geophysical data. There is probably more prospective terrane in CT for these deposits but we need better definition of the geophysical anomalies to know whether they are related to serpentinite or mafic volcanic rocks. It is not always clear (Griscom and others, in press).

We included the ultramafic rock-rich NFT as level-3 potential in spite of the dearth deposits there. Irwin (1972) suggested that a possible explanation for the lack of chromite deposits is that the composition of the ultramafic rocks may be incompatible with chromite deposits, which occur mainly in dunite (Rice, 1957). We still lack data on composition of the rocks. There is a chromite prospect south of Douglas City, reported by Irwin (1972). This prospect is located in NFT, east of the boundary of the western half of the Redding quadrangle (Wells and Hawkes, 1965).

DISCUSSION

Lithology may be an important controlling factor in the occurrence of mineral deposits, but similar lithologies occur in most of the terranes in the western half of the Redding quadrangle. In spite of that, some very similar terranes, such as RCT and NFT, both of which are composed mostly of dismembered ophiolitic rocks (Irwin, 1981; Fraticelli and others, 1987) have very different mineral endowments. For example, the common Mn-chert and podiform chromite deposits of RCT are not found in NFT, for no apparent reason (Irwin, 1972). Similarly, argillite-graywacke hosted Au-quartz veins common in the WHT (Hayfork and Harrison Gulch districts) and in similar lithologies in terranes in the eastern part of the Redding quadrangle (fig. 4b), are not found in similar lithologies in WJT and the terranes of the Coast Ranges. Au anomalies do occur in some of those areas. It is hard to believe, however, that significant Au-quartz vein deposits, if they do occur, have not been found. Perhaps the association of these deposits with granitic plutons in the more easterly Klamath Mountains terranes explains their lack further west. There are fewer plutons in the WJT, but they do occur there. None have been found in the Coast Ranges, although geophysical data suggests some are present but not exposed at the surface (Griscom and others, in press).

Coast Ranges terranes were accreted later than the Klamath Mountains terranes, in the Cretaceous and early Tertiary. Syn- or post-accretion plutons which may have developed in those areas, and any of their associated Au-quartz vein deposits, may simply not yet have been exposed at the current level of erosion. Perhaps Au anomalies in the Coast Ranges are indicative of the occurrence of VMS deposits in those drainages, which could be part of the melanges, or part of coherent blocks that contain them separated by melange matrix. Island Mountain, a quite large VMS, is of that origin (Koski and others, 1991). Unfortunately, stream-sediment samples were not collected in the vicinity of Island Mountain because of logistical problems.

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LIST OF FIGURES

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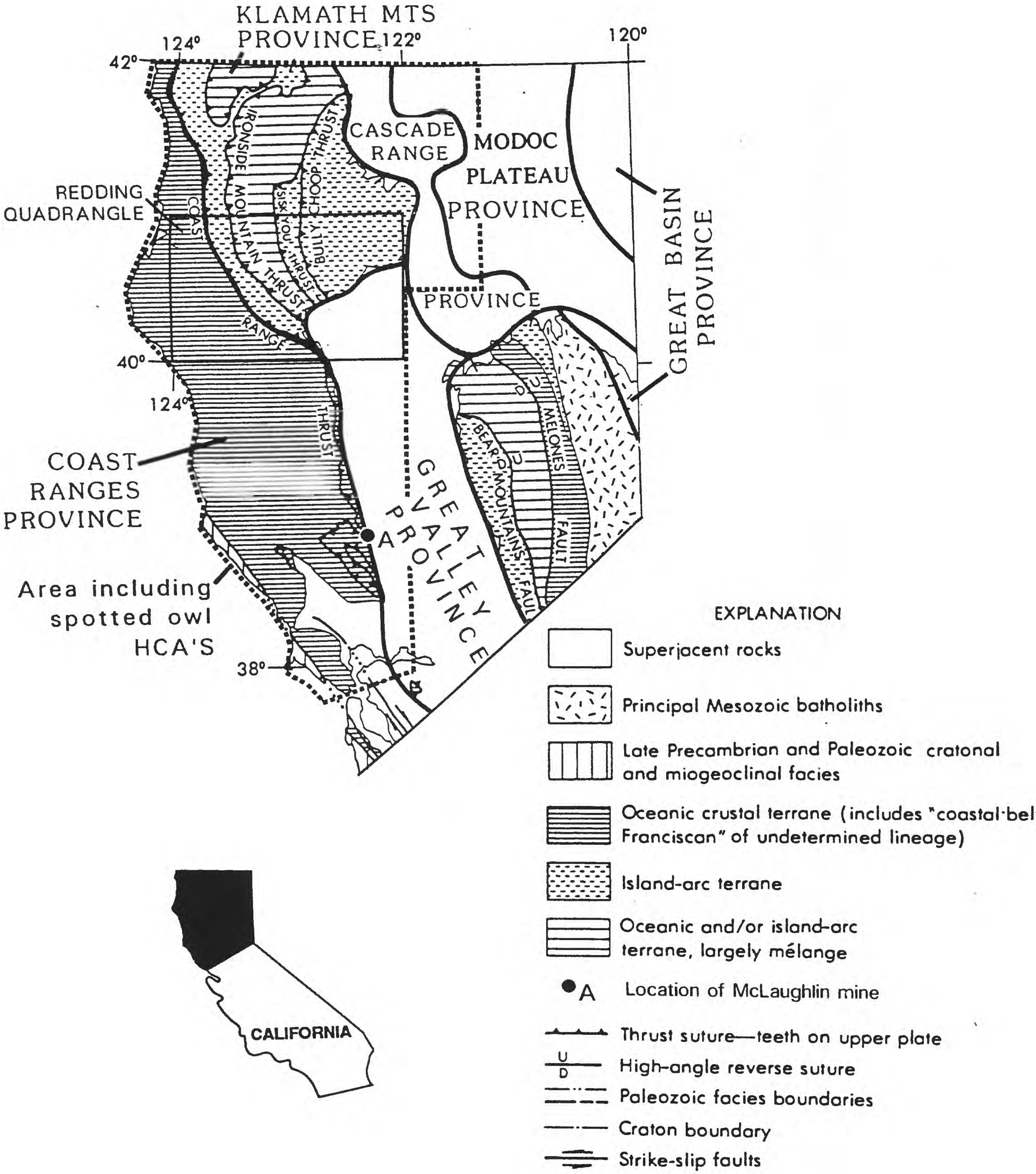
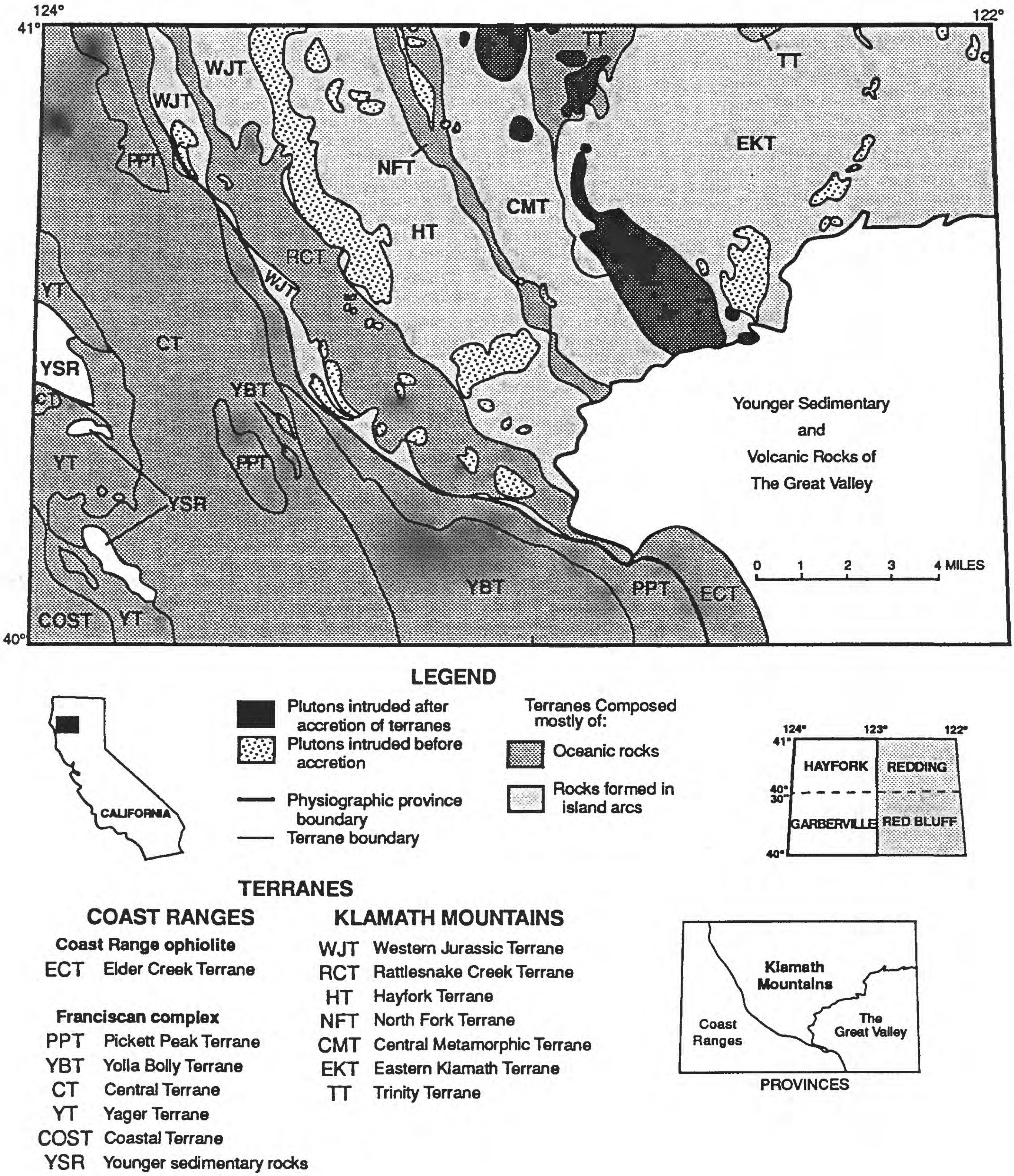
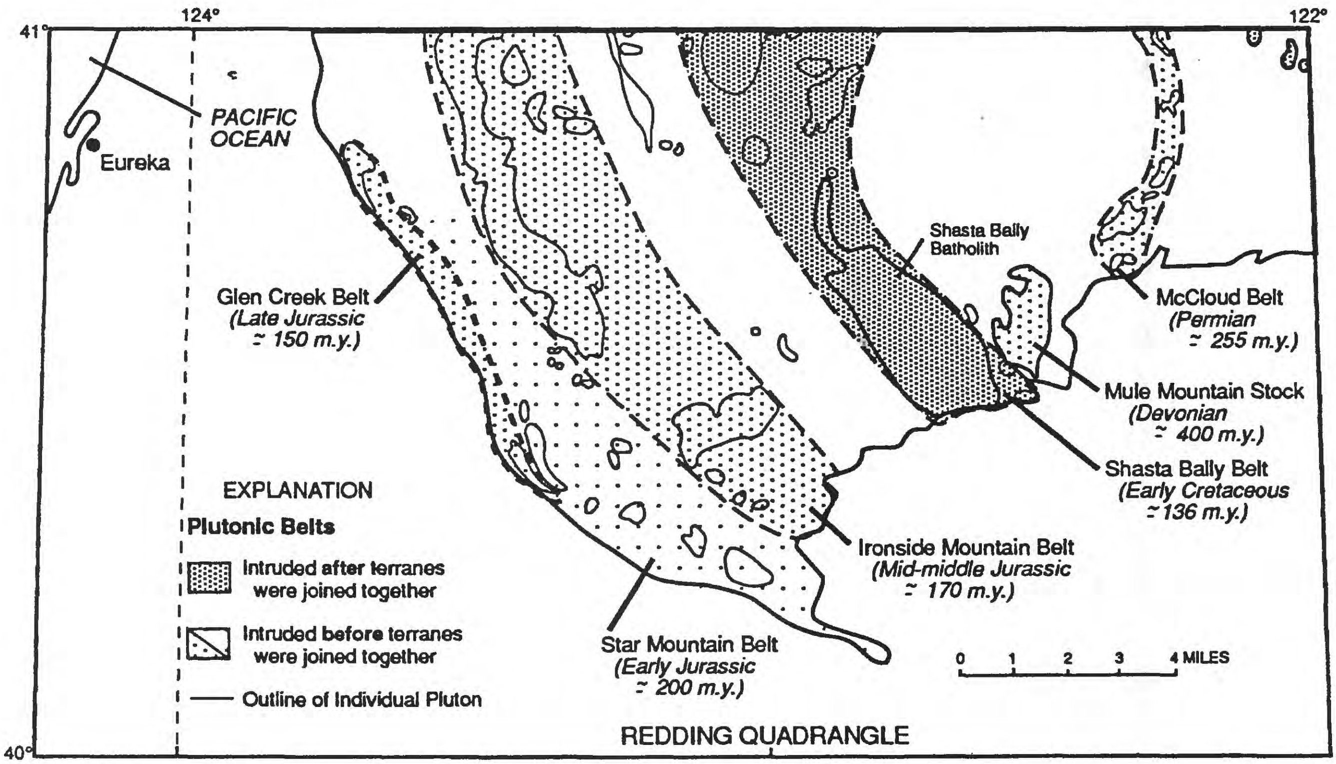
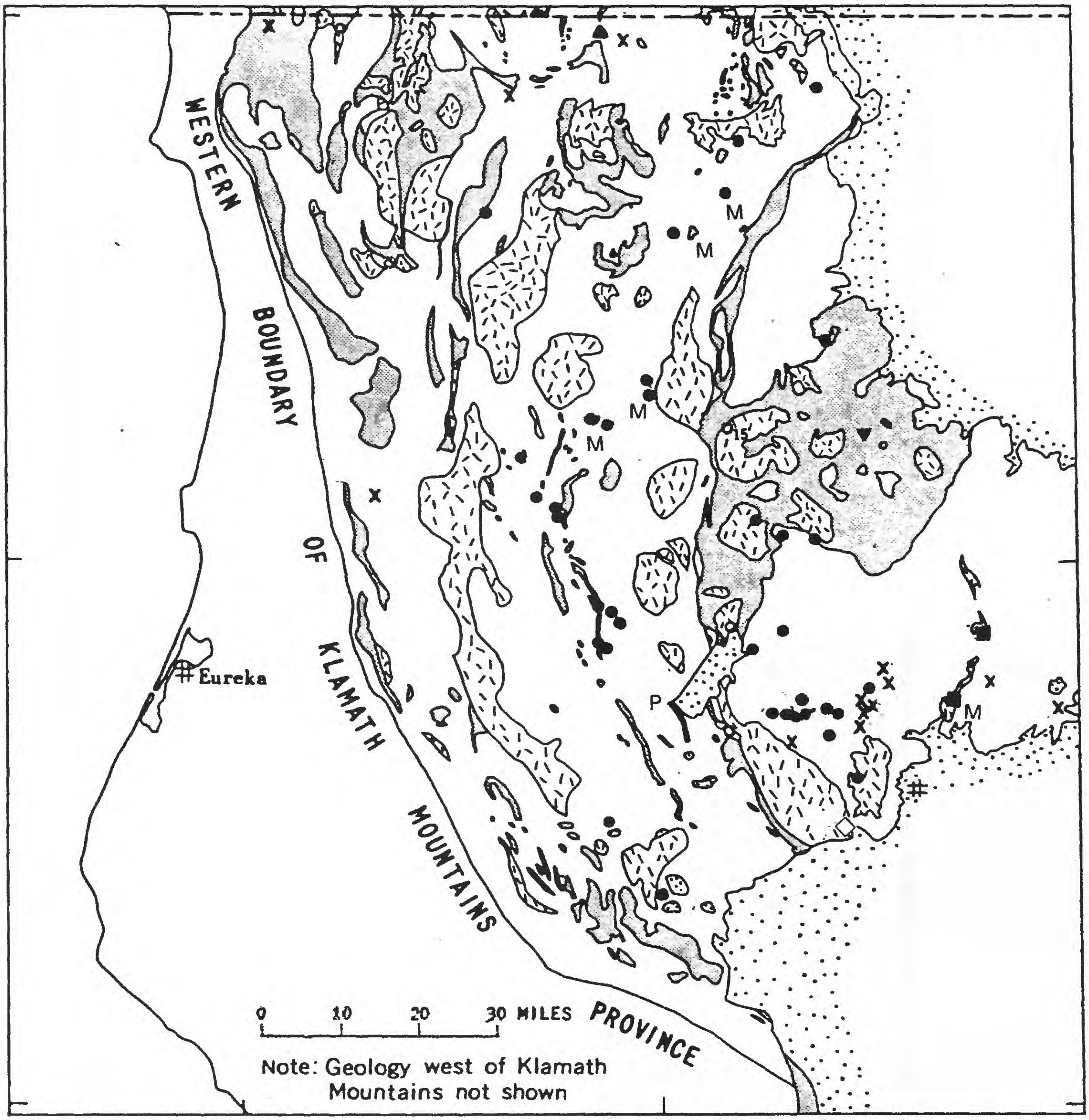


KLAMATH MTS PROVINCE
124°
122°
120°
42°
CASCADE RANGE
MODOC PLATEAU PROVINCE
REDDING QUADRANGLE
COAST
IRONSIDE MOUNTAIN THRUST
SISKIYOU THRUST
BULLY CHOOP THRUST
PROVINCE
GREAT BASIN PROVINCE
RANGE
40°
124°
THRUST
COAST RANGES PROVINCE
GREAT VALLEY PROVINCE
BEAR MOUNTAINS FAULT
MELONES FAULT
U
D
A
Area including spotted owl HCA'S
38°
EXPLANATION
Superjacent rocks
Principal Mesozoic batholiths
Late Precambrian and Paleozoic cratonal and miogeoclinal facies
Oceanic crustal terrane (includes "coastal-belt Franciscan" of undetermined lineage)
Island-arc terrane
Oceanic and/or island-arc terrane, largely mélange
A Location of McLaughlin mine
Thrust suture—teeth on upper plate
High-angle reverse suture
Paleozoic facies boundaries
Craton boundary
Strike-slip faults
CALIFORNIA



124°
41°
122°
40°
WJT
WJT
PPT
NFT
HT
CMT
EKT
TT
TT
RCT
WJT
YT
YSR
CT
YBT
YT
PPT
YSR
YBT
PPT
ECT
COST
YT
Younger Sedimentary and Volcanic Rocks of The Great Valley
0 1 2 3 4 MILES
LEGEND
Plutons intruded after accretion of terranes
Plutons intruded before accretion
Physiographic province boundary
Terrane boundary
Terranes Composed mostly of:
Oceanic rocks
Rocks formed in island arcs
CALIFORNIA
124° 123° 122°
41°
40° 30'
40°
HAYFORK
REDDING
GARBERVILLE
RED BLUFF
TERRANES
COAST RANGES
Coast Range ophiolite
ECT Elder Creek Terrane
Franciscan complex
PPT Pickett Peak Terrane
YBT Yolla Bolly Terrane
CT Central Terrane
YT Yager Terrane
COST Coastal Terrane
YSR Younger sedimentary rocks
KLAMATH MOUNTAINS
WJT Western Jurassic Terrane
RCT Rattlesnake Creek Terrane
HT Hayfork Terrane
NFT North Fork Terrane
CMT Central Metamorphic Terrane
EKT Eastern Klamath Terrane
TT Trinity Terrane
Klamath Mountains
Coast Ranges
The Great Valley
PROVINCES

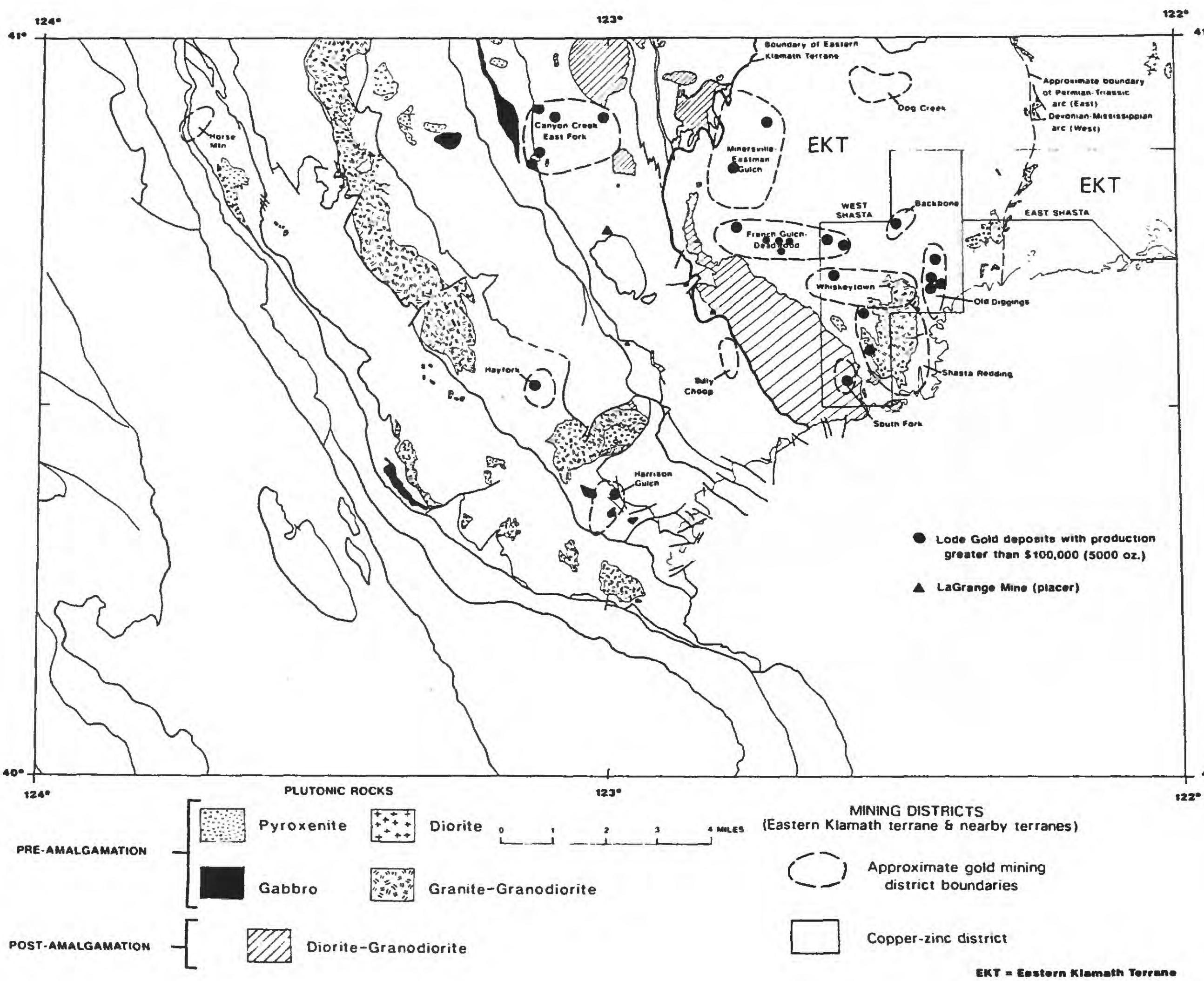

41°
124°
122°
PACIFIC OCEAN
Eureka
Shasta Bally Batholith
Glen Creek Belt
(Late Jurassic
≃ 150 m.y.)
McCloud Belt
(Permian
≃ 255 m.y.)
Mule Mountain Stock
(Devonian
≃ 400 m.y.)
Shasta Bally Belt
(Early Cretaceous
≃136 m.y.)
EXPLANATION
Plutonic Belts
Intruded after terranes were joined together
Intruded before terranes were joined together
Outline of Individual Pluton
Ironside Mountain Belt
(Mid-middle Jurassic
≃ 170 m.y.)
Star Mountain Belt
(Early Jurassic
≃ 200 m.y.)
0 1 2 3 4 MILES
40°
REDDING QUADRANGLE



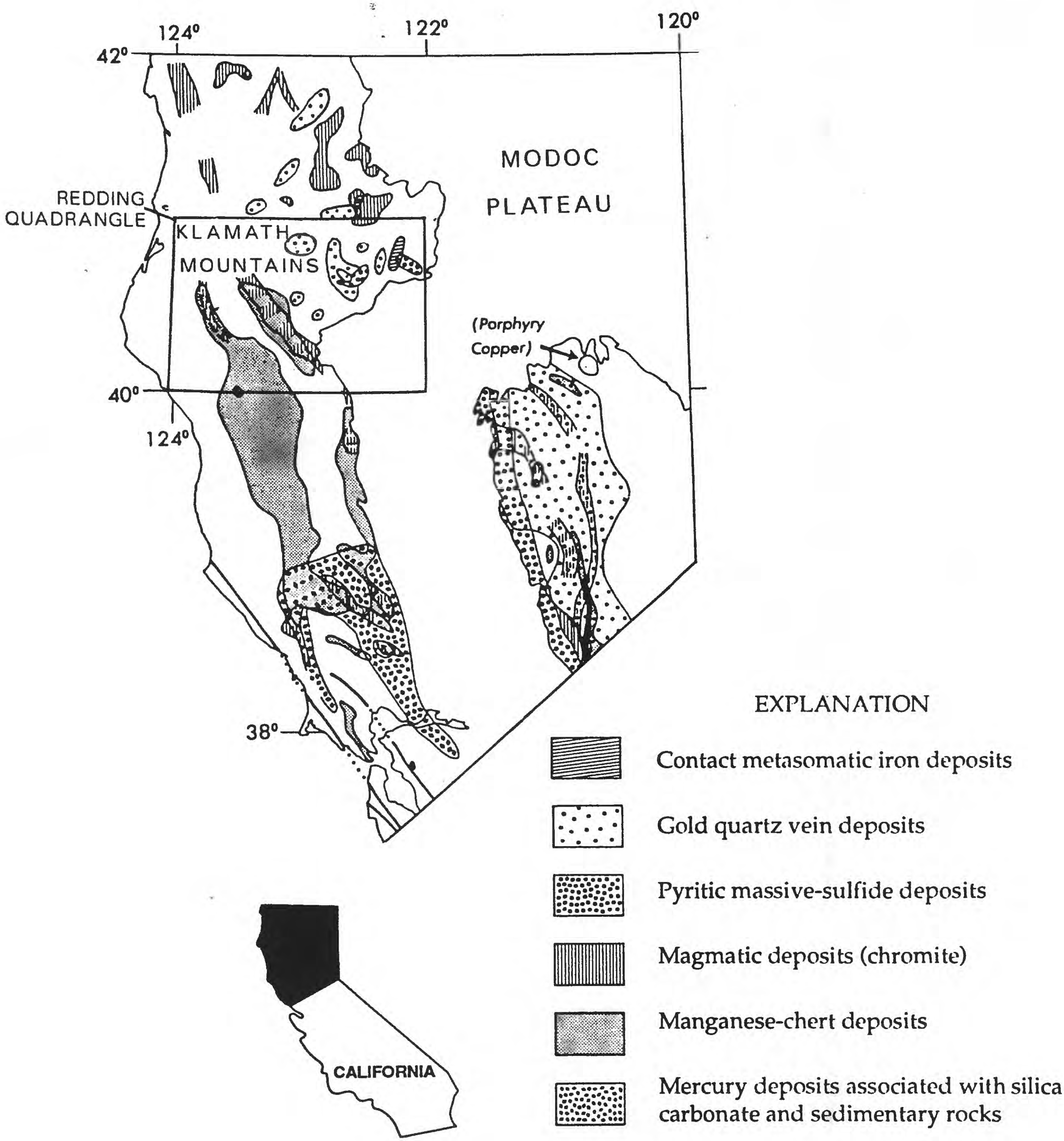
EXPLANATION

- Cretaceous and younger rocks
- Granitic rocks
- Ultramafic rocks
- Paleozoic and Mesozoic metasedimentary and metavolcanic rocks

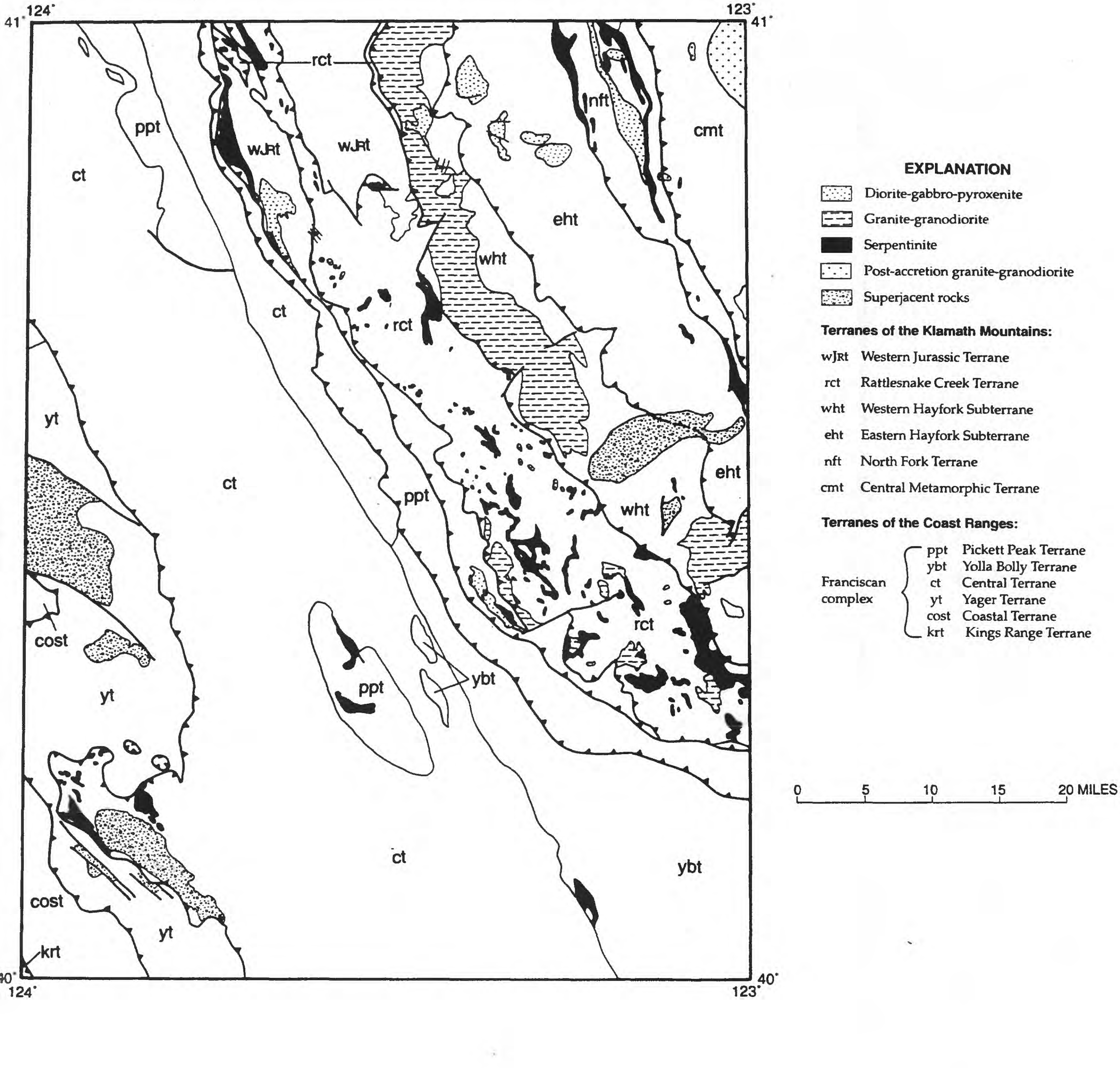
- ■ Iron
- ◇ Silver
- M Manganese
- ● Gold
- ▼ Mercury (Altoona)
- P Placer gold (La Grange Mine)
- ▲ Chromite (Selad Creek deposits)
- x Base-metal deposit, chiefly massive sulfide containing copper, lead, zinc, pyrite, gold, and silver; includes some disseminated and vein types

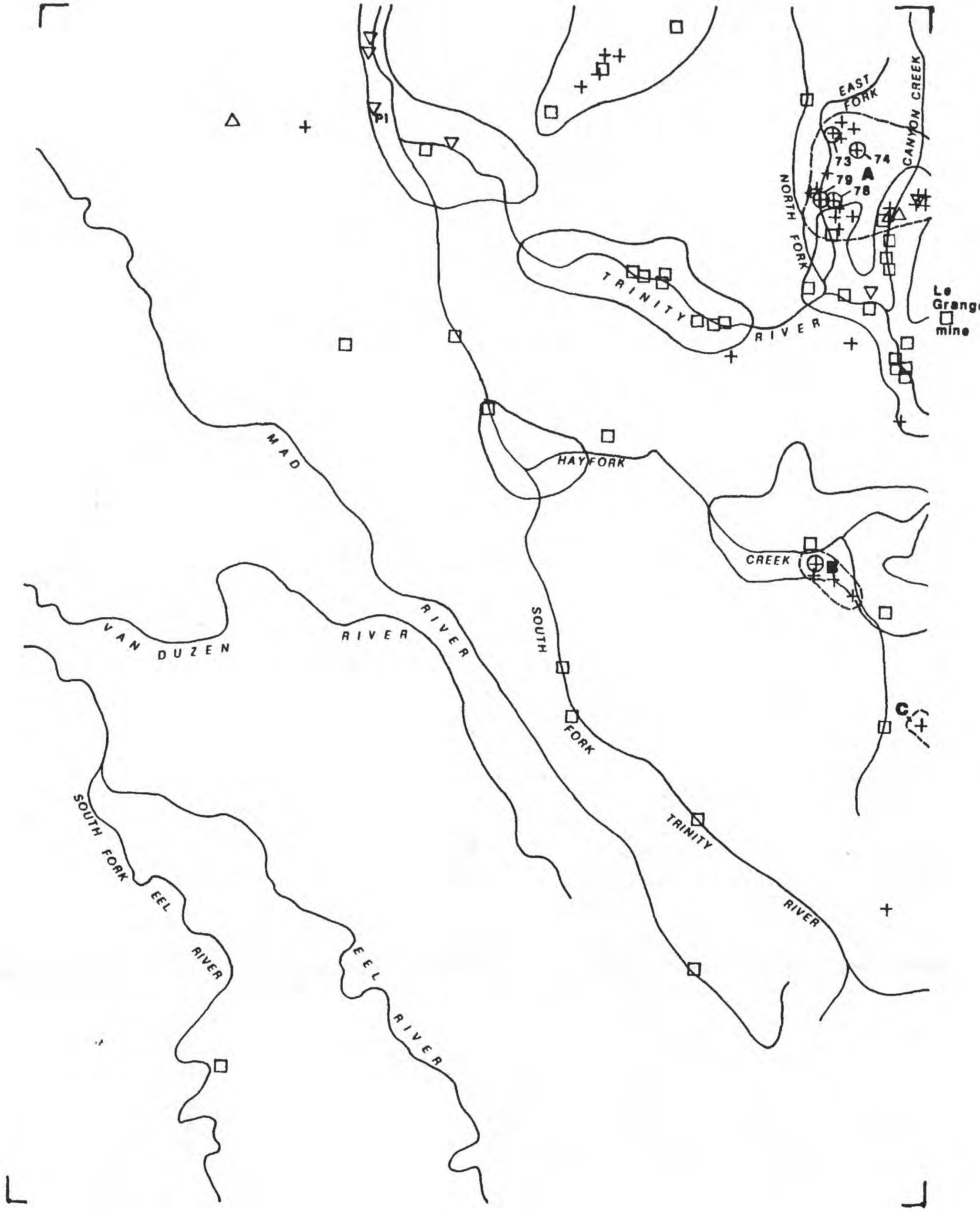


124°
123°
122°
41°
40°
Boundary of Eastern Klamath Terrane
Dog Creek
Approximate boundary of Permian-Triassic arc (East)
Devonian-Mississippian arc (West)
EKT
EKT
Canyon Creek East Fork
Minersville-Eastman Gulch
Horse Mtn
WEST SHASTA
Backbone
EAST SHASTA
French Gulch-Deadwood
Whiskeytown
Old Diggings
Hayfork
Sully Choop
Shasta Redding
South Fork
Harrison Gulch
Lode Gold deposits with production greater than $100,000 (5000 oz.)
LaGrange Mine (placer)
PLUTONIC ROCKS
PRE-AMALGAMATION
Pyroxenite
Diorite
Gabbro
Granite-Granodiorite
POST-AMALGAMATION
Diorite-Granodiorite
0
1
2
3
4 MILES
MINING DISTRICTS
(Eastern Klamath terrane & nearby terranes)
Approximate gold mining district boundaries
Copper-zinc district
EKT = Eastern Klamath Terrane



124°
122°
120°
42°
40°
124°
38°
REDDING QUADRANGLE
KLAMATH MOUNTAINS
MODOC PLATEAU
(Porphyry Copper)
CALIFORNIA
EXPLANATION
Contact metasomatic iron deposits
Gold quartz vein deposits
Pyritic massive-sulfide deposits
Magmatic deposits (chromite)
Manganese-chert deposits
Mercury deposits associated with silica carbonate and sedimentary rocks


124°
123°
41°
41°
40°
40°
124°
123°
rct
ppt
wJRt
wJRt
ct
nft
cmt
eht
wht
ct
rct
yt
ct
ppt
eht
wht
cost
rct
yt
ppt
ybt
ct
ybt
cost
yt
krt
EXPLANATION
Diorite-gabbro-pyroxenite
Granite-granodiorite
Serpentinite
Post-accretion granite-granodiorite
Superjacent rocks
Terranes of the Klamath Mountains:
wJRt Western Jurassic Terrane
rct Rattlesnake Creek Terrane
wht Western Hayfork Subterrane
eht Eastern Hayfork Subterrane
nft North Fork Terrane
cmt Central Metamorphic Terrane
Terranes of the Coast Ranges:
Franciscan complex
ppt Pickett Peak Terrane
ybt Yolla Bolly Terrane
ct Central Terrane
yt Yager Terrane
cost Coastal Terrane
krt Kings Range Terrane
0
5
10
15
20 MILES



EXPLANATION

Lode Gold Mines and Prospects

+ Mine or prospect

⊕ Mine or prospect with >5,000 oz production[1]

△ Hg mine or prospect

Placer Mines and Prospects

□ Placer mine or prospect, CDM&G reports

▽ Placer containing Pt and Au[2]

⬭ Area containing large number of small placer deposits

[1]Numbers refer to Hotz, 1971, Table 8.

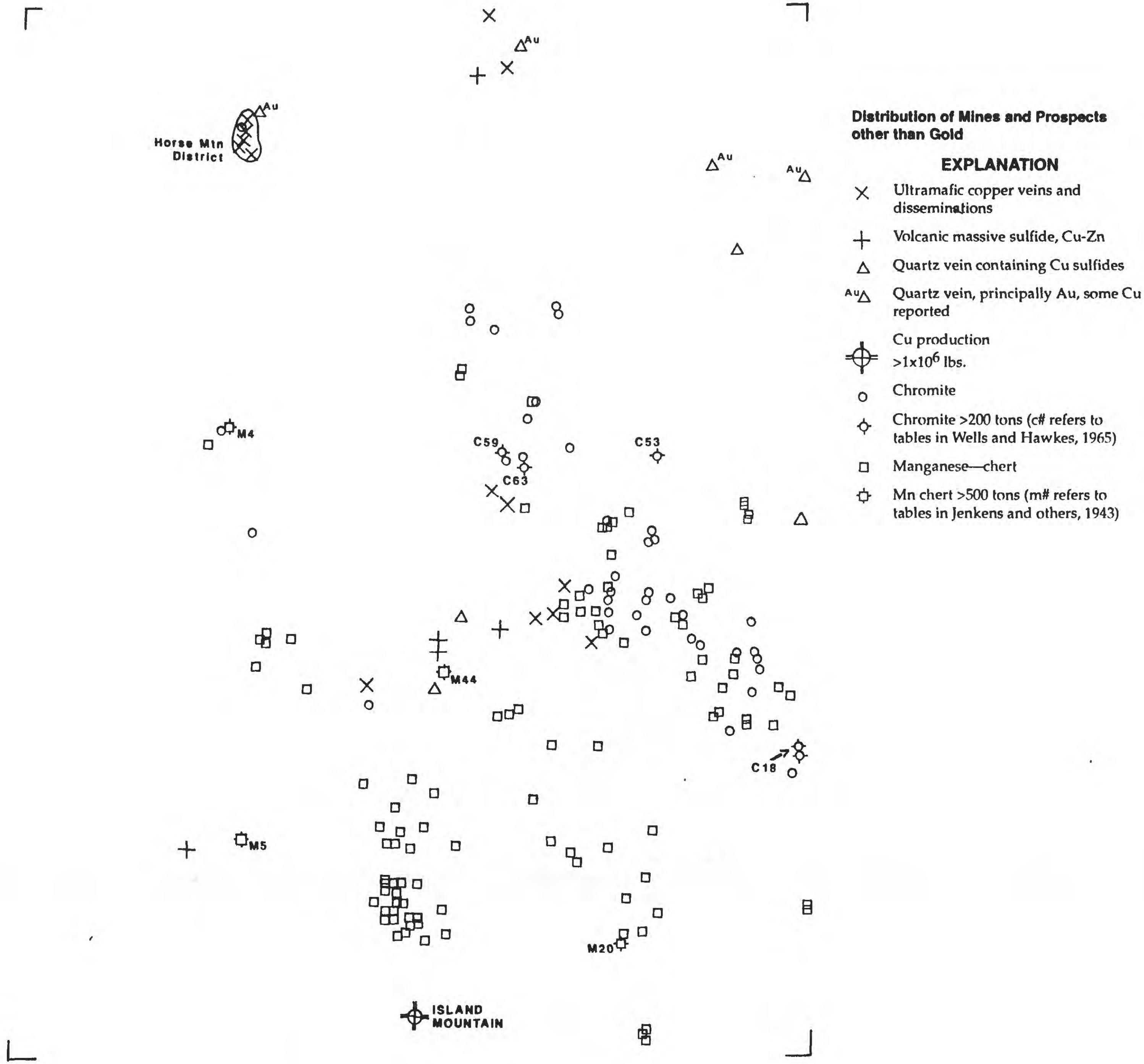
[2]Pl, placer deposit referred to in text

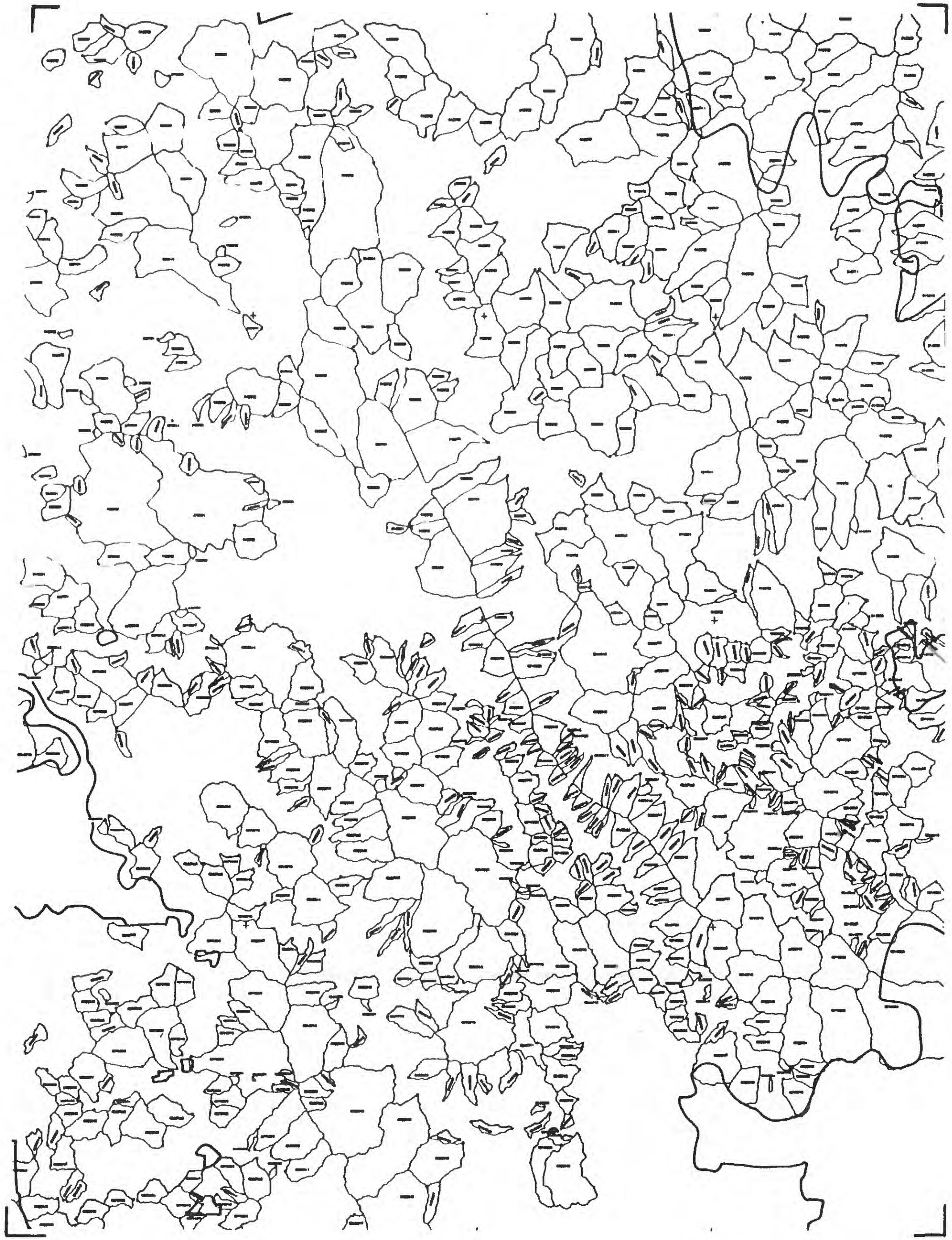
Gold District

A Canyon Creek—East Fork

B Hayfork

C Harrison Gulch


Distribution of Mines and Prospects other than Gold
EXPLANATION
Ultramafic copper veins and disseminations
Volcanic massive sulfide, Cu-Zn
Quartz vein containing Cu sulfides
Au Quartz vein, principally Au, some Cu reported
Cu production >1x10^6 lbs.
Chromite
Chromite >200 tons (c# refers to tables in Wells and Hawkes, 1965)
Manganese—chert
Mn chert >500 tons (m# refers to tables in Jenkens and others, 1943)
Horse Mtn District
Au
C59
C63
C53
C18
M4
M5
M44
M20
ISLAND MOUNTAIN



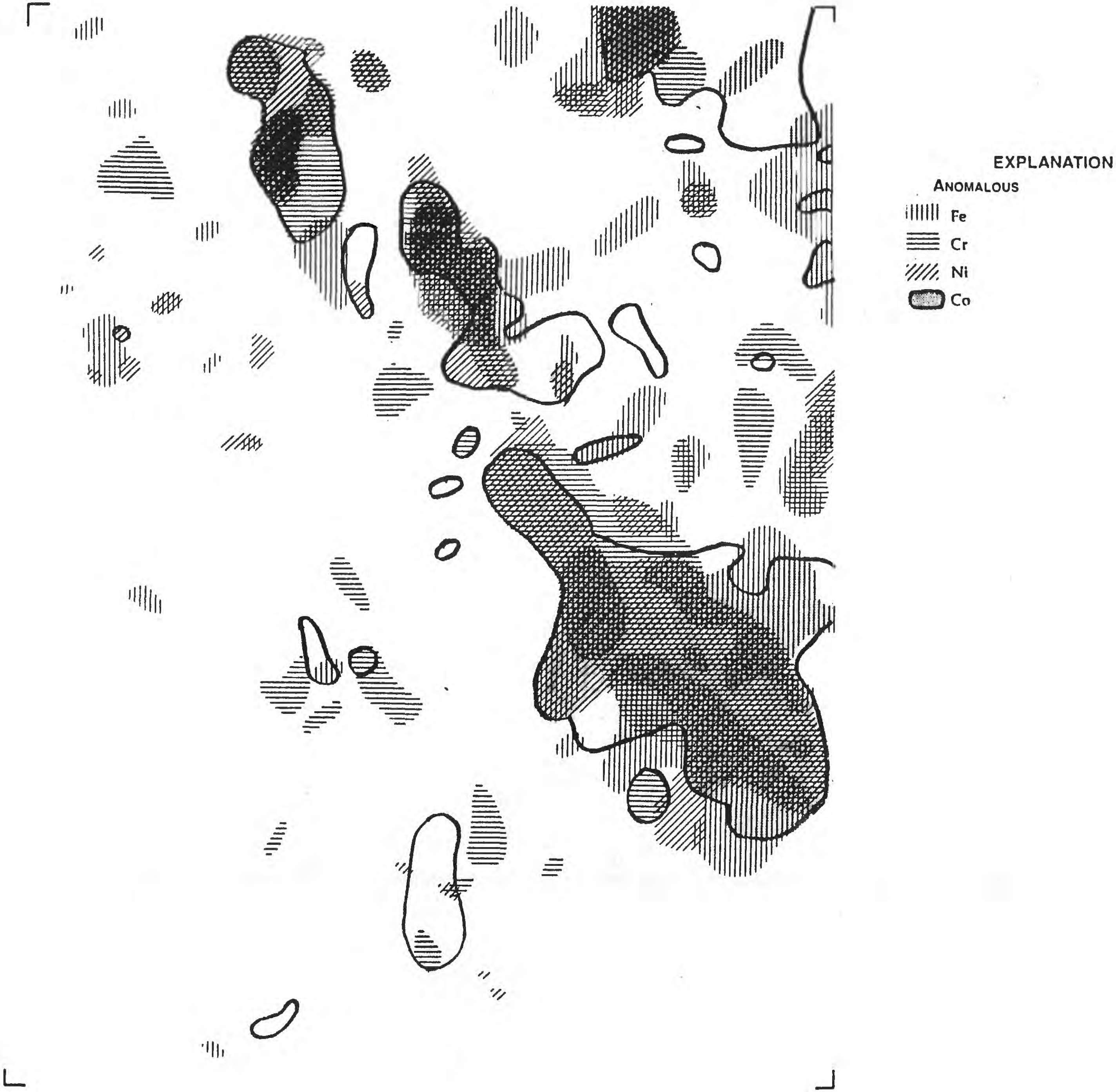
EXPLANATION

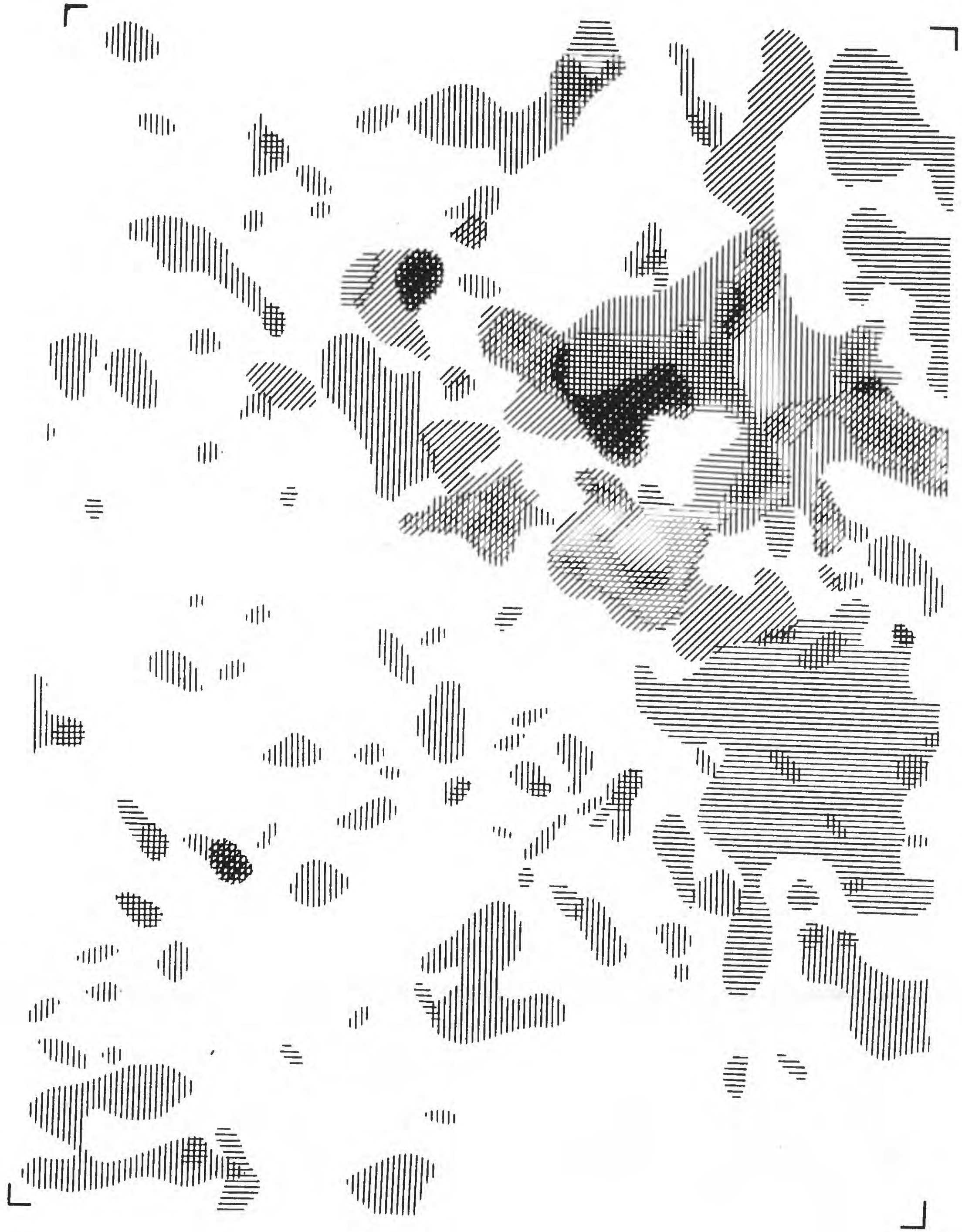
—— Drainage outline

—— Approximate boundaries of wilderness areas, roadless areas, conservation areas, primitive areas, Indian Reservations, and State Park lands

Only drainages sampled are shown

[1]only drainages sampled are shown


EXPLANATION
ANOMALOUS
Fe
Cr
Ni
Co



EXPLANATION

ANOMALOUS

- Ba
- Mn
- Sn


EXPLANATION
Cu in -80 mesh stream sediment and/or C3 panned concentrate
Zn in -80 mesh stream sediment and/or C3 panned concentrate
Pb in -80 mesh stream sediment and/or C3 panned concentrate

EXPLANATION

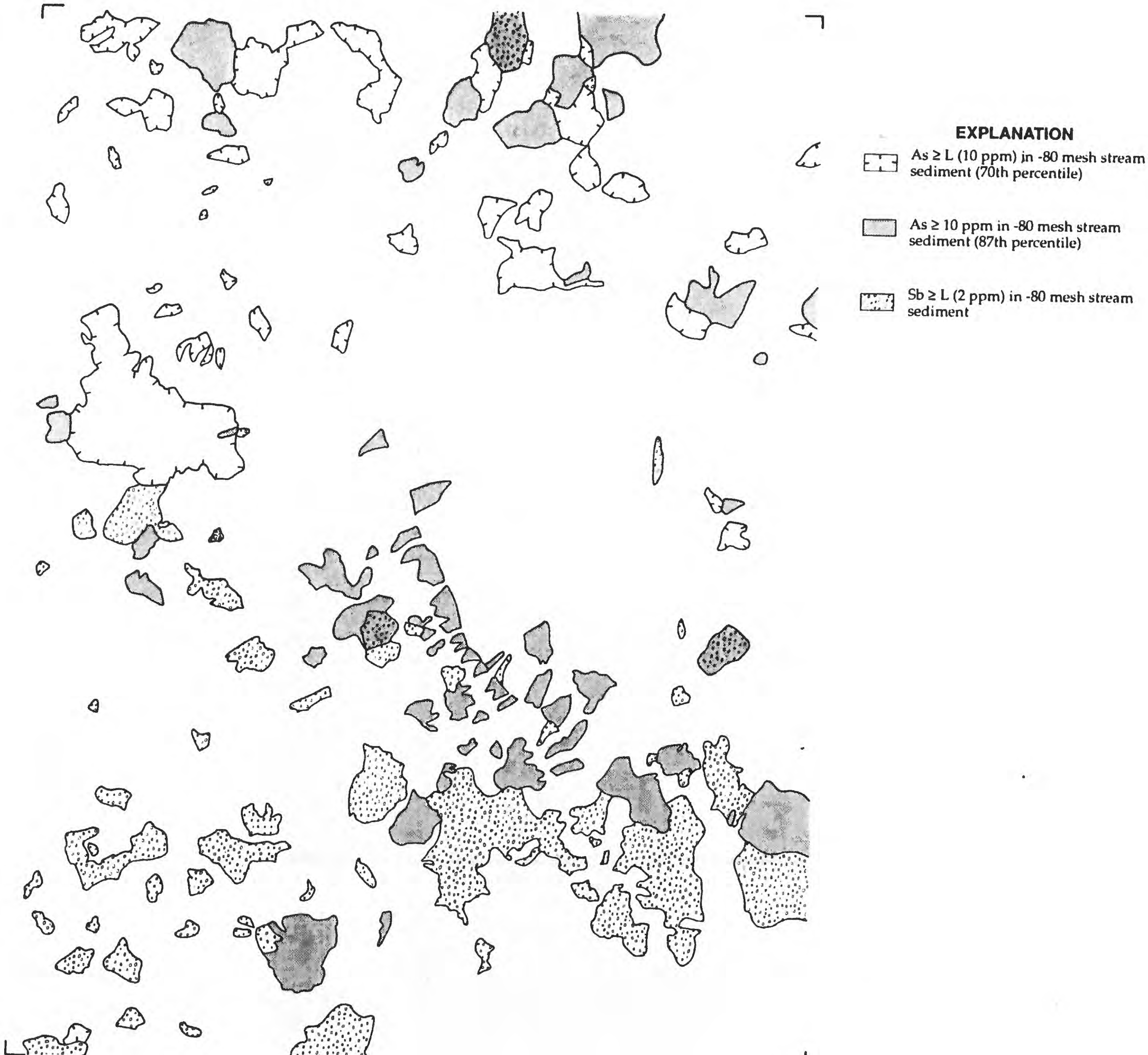
Pyrite and other sulfides in C3 panned concentrate

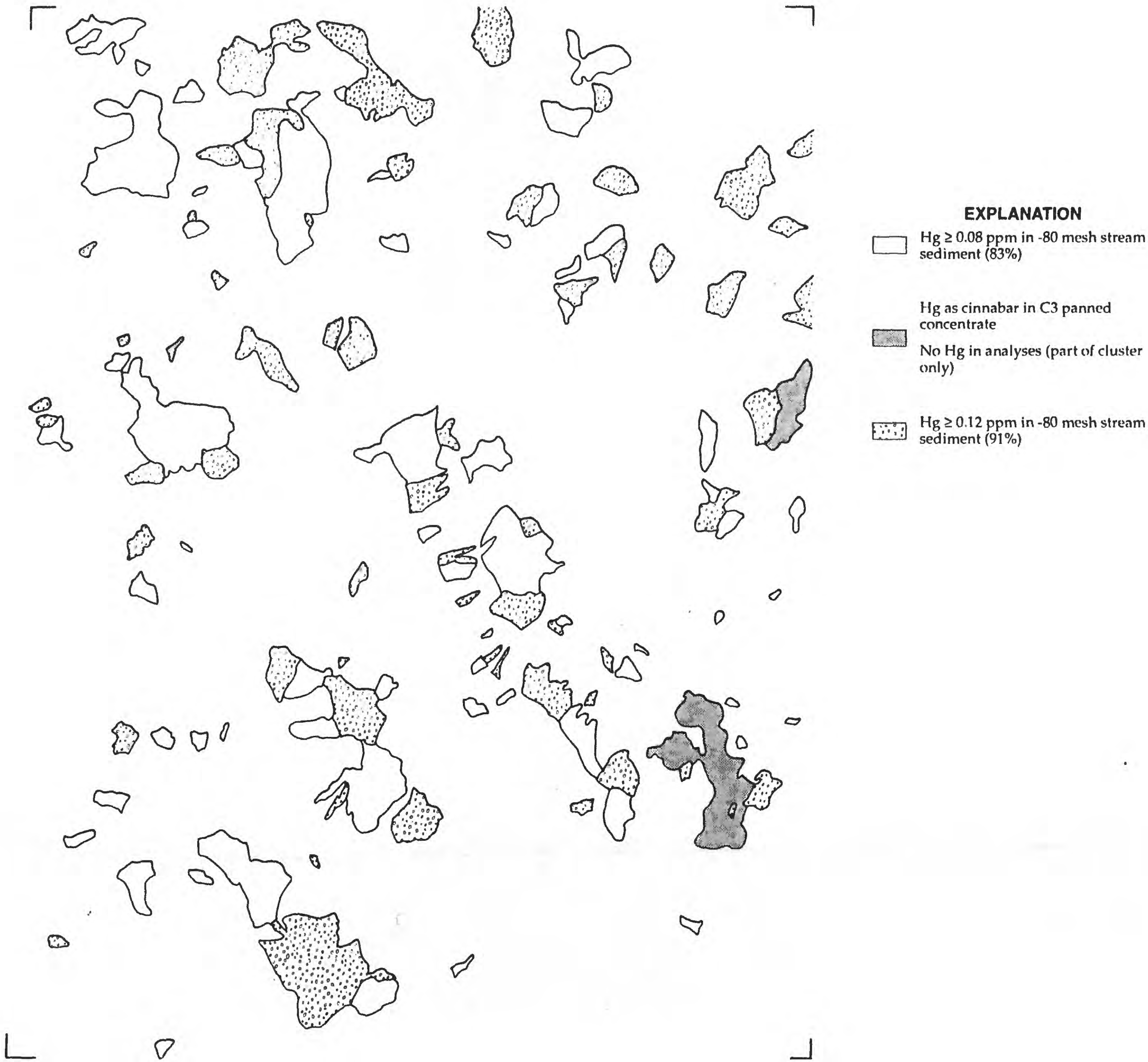
EXPLANATION

Scheelite in C3 panned concentrate

W ≥ L (50 ppm) in -80 mesh stream sediment

W ≥ 100 ppm in C3 panned concentrate


EXPLANATION
As ≥ L (10 ppm) in -80 mesh stream sediment (70th percentile)
As ≥ 10 ppm in -80 mesh stream sediment (87th percentile)
Sb ≥ L (2 ppm) in -80 mesh stream sediment


EXPLANATION
Hg ≥ 0.08 ppm in -80 mesh stream sediment (83%)
Hg as cinnabar in C3 panned concentrate
No Hg in analyses (part of cluster only)
Hg ≥ 0.12 ppm in -80 mesh stream sediment (91%)


EXPLANATION
Au ≥ L (.05 ppm) in stream sediment
Au ≥ L (10 ppm) in C3 panned concentrate
Au visible in C3
Ag ≥ L (.5 ppm) in stream sediment
Ag ≥ L(1 ppm) in C3 panned concentrate
Au + Ag


EXPLANATION
As in -80 mesh stream sediment
Hg in -80 mesh stream sediment
Hg in C_3 panned concentrate
Au in -80 mesh stream sediment
Au in C_3 panned concentrate
Au visible in C_3 panned concentrate
Ag in -80 mesh stream sediment
Ag in C_3 panned concentrate


EXPLANATION
Au-bearing drainage (+Ag) where Ag is also present
Ag-bearing drainage, no Au present
Au + Hg
Au + As
Au + (±Cu±Pb±Zn) Elements present are listed
W Scheelite in C_3, or detectable within stream sediment or panned concentrate
3 Au anomaly number
A1 Ag anomaly number
KLAMATH MOUNTAINS
COAST RANGES
SOUTH FORK MOUNTAIN FAULT
Cu+Pb+Zn
Cu+Pb
Cu+Zn
Cu+Pb+(Zn)
+Ag
Cu
Zn
Ag
W

EXPLANATION

Qualitative Probability Levels

Level 1—Mines and propects in area

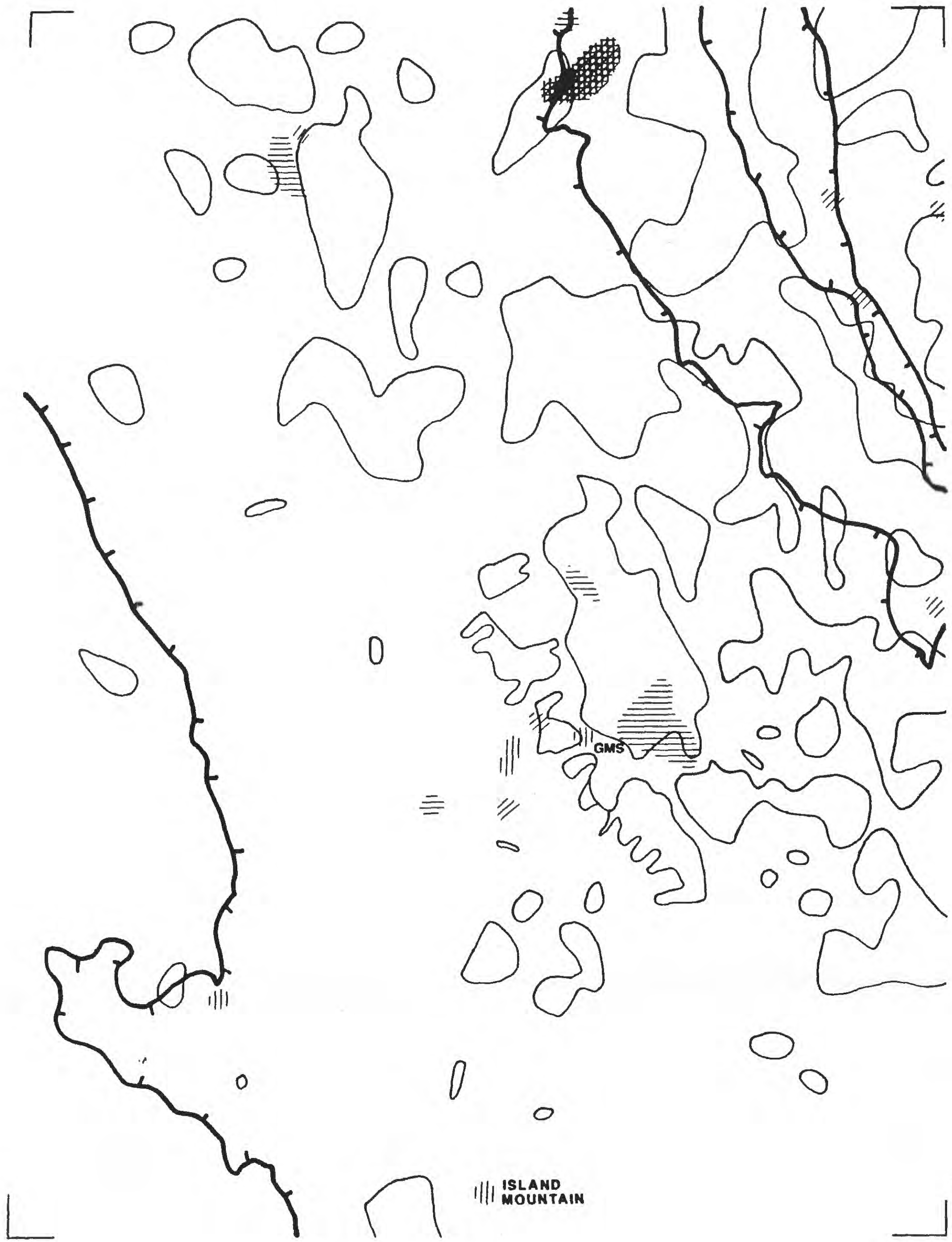
Level 2—Favorable geochemistry. Presence of gold in stream sediments,[1] ±Hg, As, scheelite, Cu, Pb, and Zn.

P Isolated placer deposit/prospect

Level 3A—Pluton intruding terrane—Includes pluton and surrounding wall rocks

Level 3B—Geophysical evidence of pluton in subsurface

[1]If drainage contains Ag and no Au, it is included if other elements listed are present, alone or in combination



EXPLANATION

Level 1—Mines and prospects present

- VMS/SMS Cu-Zn
- Ultramafic Cu-Au
- Other (Au-vein with Cu, or Cu-vein)

Level 2—Favorable geochemistry (occurrence of Cu ± Zn, ± Pb, ± Ag, ± Au in stream sediment.)

Areas containing ultramafic rock are favorable for ultramafic Cu-Au.

Level 3—Favorable lithology—All terranes with considerable volcanic and volcaniclastic rocks are permissible for VMS/SMS Cu-Zn. ct, wJRt, rct, wht, nft are considered most permissive, but any terrane on the map has at least some areas of permissive lithology. All areas underlain by ultramafic rocks are permissive for occurrence of ultramafic Cu-Au.

EXPLANATION

Level 1—Presence of mines or prospects

Level 2—Favorable geochemistry based on the empirical association of scheelite or W anomaly (see text) with Mn-chert deposits. It works best in ct and may not be applicable in other terranes, particularly east of rct.

Level 3—Favorable lithology. Terranes with mafic volcanic rocks interbedded with argillite and greywacke such as ct, ybt, ppt, and rct are most favorable.

EXPLANATION

Level 1—Presence of mines and prospects

Level 3—Favorable lithology. Presence of ultramafic rocks or geophysical indication of their presence[1].

[1]In some cases, Level 3 areas are extended from outcrops of ultramafic rock on the basis of geophysical data, or are based on geophysical data in the absence of known, surface exposures of ultramafic rock (see text).