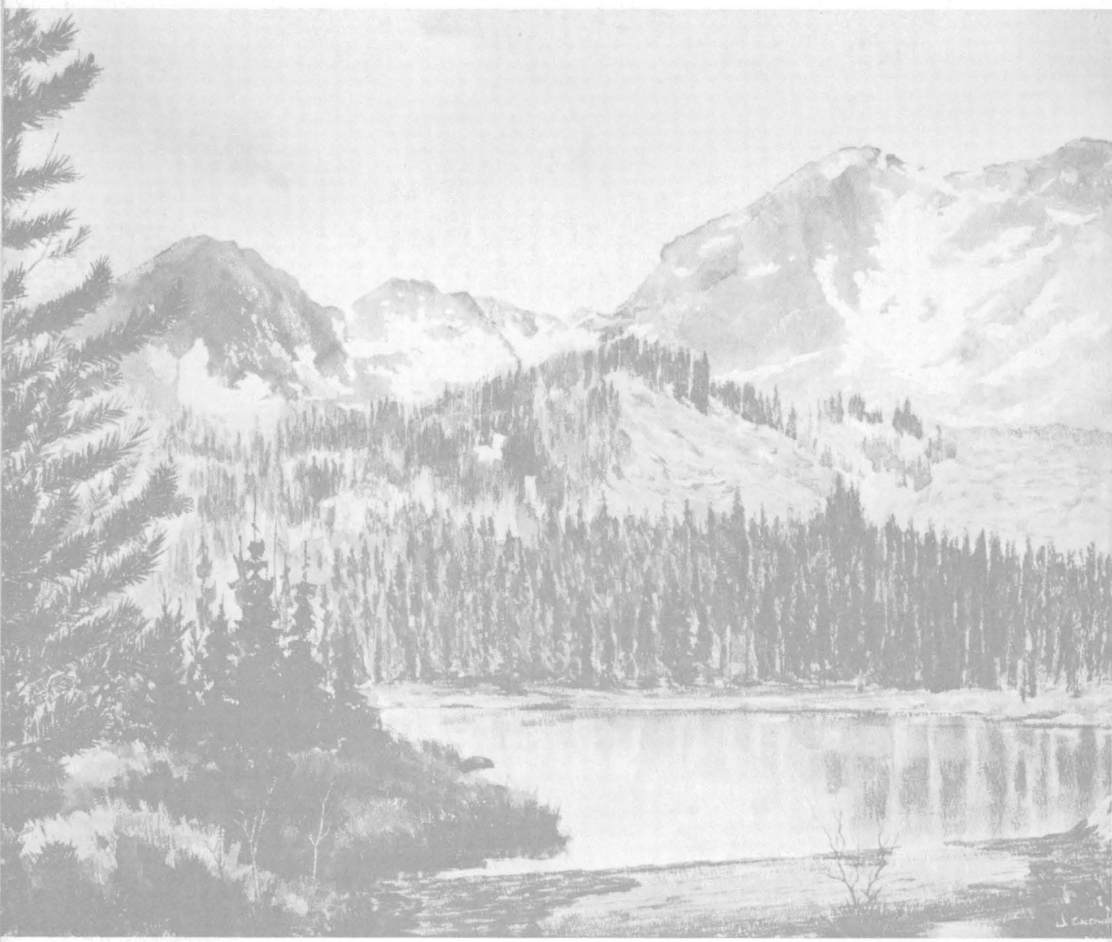
STUDIES RELATED TO WILDERNESS

WILDERNESS AREAS



MINARETS, CALIFORNIA

GEOLOGICAL SURVEY BULLETIN 1516-A-D

Mineral Resources of the Minarets Wilderness and Adjacent Areas, Madera and Mono Counties, California

By U.S. GEOLOGICAL SURVEY *and* U.S. BUREAU OF MINES

A. Regional Setting, Geology, and Geochemical Studies of the Minarets Wilderness and Adjacent Areas, Madera and Mono Counties, California

By N. KING HUBER, U.S. GEOLOGICAL SURVEY

B. Geophysical Studies of the Minarets Wilderness and Adjacent Areas, Madera and Mono Counties, California

By HOWARD W. OLIVER, U.S. GEOLOGICAL SURVEY

C. Geothermal-Resource Evaluation of the Minarets Wilderness and Adjacent Areas, Madera and Mono Counties, California

By ROY A. BAILEY, U.S. GEOLOGICAL SURVEY

D. Economic-Mineral Appraisal of the Minarets Wilderness and Adjacent Areas, Madera and Mono Counties, California

By HORACE K. THURBER, MICHAEL S. MILLER, C. THOMAS HILLMAN, DAVID S. LINDSEY, *and* RICHARD W. MORRIS, U.S. BUREAU OF MINES

STUDIES RELATED TO WILDERNESS — WILDERNESS AREAS

GEOLOGICAL SURVEY BULLETIN 1516-A-D

An evaluation of the mineral potential of the area

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1982

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STUDIES RELATED TO WILDERNESS

WILDERNESS AREAS

In accordance with the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and the Joint Conference Report on Senate Bill 4, 88th Congress, the U.S. Geological Survey and U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Studies and reports of all primitive areas have been completed. Areas officially designated as "wilderness," "wild," or "canoe" when the Act was passed were incorporated into the National Wilderness Preservation System, and some of them have been studied and others are presently being studied. The Act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. This report discusses the results of a mineral survey of the Minarets Wilderness, California, and adjacent areas that are being considered for wilderness designation.

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MINERAL RESOURCES OF THE MINARETS WILDERNESS AND ADJACENT AREAS, MADERA AND MONO COUNTIES, CALIFORNIA

By U.S. GEOLOGICAL SURVEY and U.S. BUREAU OF MINES

SUMMARY

A mineral survey of the Minarets Wilderness and adjacent areas in the central Sierra Nevada, Calif., was conducted during 1973, 1974, and 1975. The total area covers about 240 mi^2 (620 km^2) in Sierra and Inyo National Forests, of which about 170 mi^2 (440 km^2) is within the officially designated Minarets Wilderness.

The mineral-resource potential was evaluated by geological, geochemical, and geophysical studies by the U.S. Geological Survey, and by examination of mineralized rocks, prospects, and mining claims by the U.S. Bureau of Mines.

The results of the survey indicate that the study area has small to moderate submarginal to paramarginal resources of copper, silver, zinc, lead, iron, and tungsten and an unevaluated potential for molybdenum resources. Limestone is present, but not of commercial quantity or quality. No other industrial minerals have been recognized in quantity. Granitic rocks have potential use as decorative stone, and sand and gravel could be produced from either alluvial deposits or glacial drift; however, these commodities are more accessible elsewhere at localities closer to markets. The study area has no potential for fossil fuels, and, because of the general geologic environment, the potential for nuclear fuel minerals is considered to be low. The study area has low geothermal potential, even though it is on the west edge of the Mono-Long Valley Known Geothermal Resource Area.

The area is underlain by metavolcanic and metasedimentary rocks that have been intruded by granitic rocks of the Sierra Nevada batholith. Pliocene and Pleistocene volcanic rocks are present locally. With few exceptions, the known occurrences of mineralized rock are confined to the metamorphic rocks, and the exceptions appear to be confined to plutonic rocks that are older than the Late Cretaceous granitic rocks which make up the bulk of the batholithic rocks in the study area.

Although no mineral production has been recorded from prospects within the study area, mines adjacent to it have produced significant amounts of gold and tungsten. Production figures are incomplete, but mines in the Mammoth mining district (fig. 1) may have produced as much as $1 million worth of gold, silver, and other metals at then-current prices. The Monte Cristo mine adjacent to the old Mammoth Mine in the Mammoth district was in production during 1978.

The Strawberry mine, adjacent to the south boundary of the study area, produced over 40,000 short ton units (363,000 kg) of tungsten trioxide (WO_3) from high-grade ore, and additional unrecorded production is believed to have come from the mine. In 1977 preparations were being made by a major company to resume tungsten production from the Strawberry mine.

Approximately 1,200 mining claims have been located in the Minarets study area since the 1890's, of which about 25 were being held during the time of investigation. Nine claims have been patented.

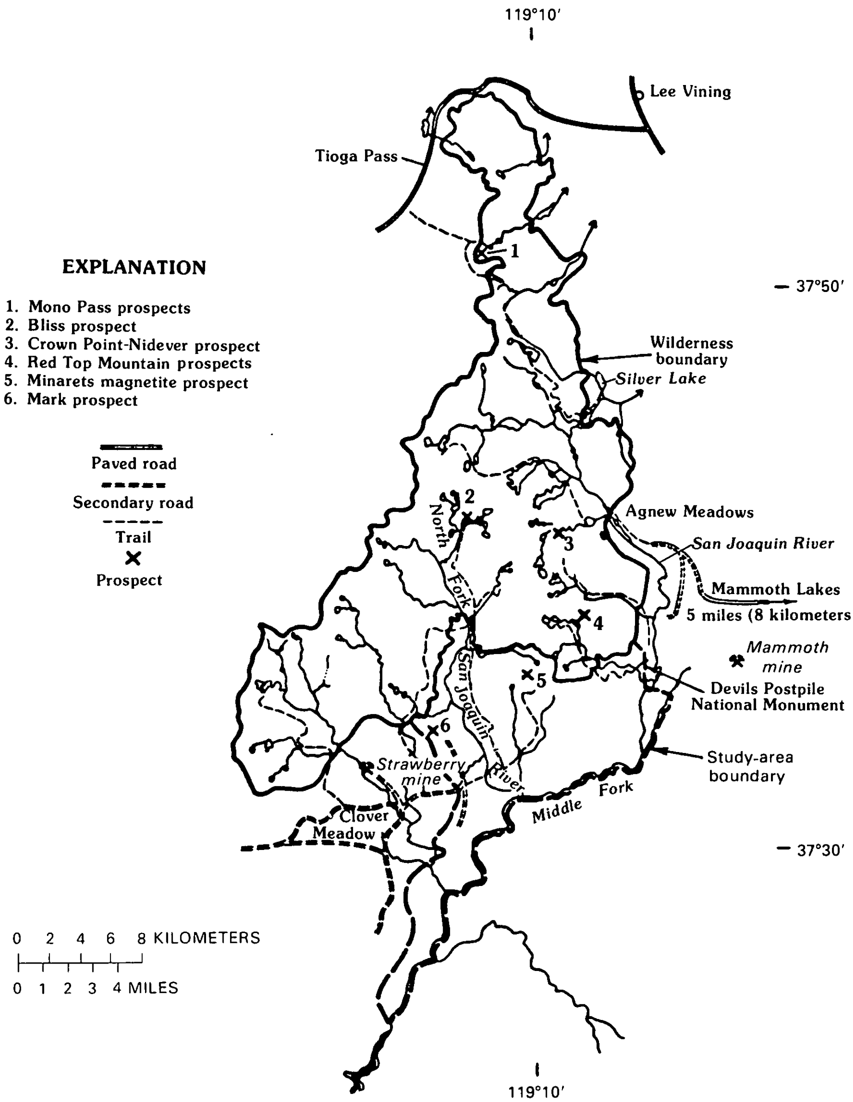

FIGURE 1.—Minarets Wilderness and adjacent areas, California, showing areas of greatest mineral-resource potential.

The Crown Point-Nidever prospect on Shadow Creek (fig. 1, No. 3) has about 9 million tons (8 million t) of submarginal resources of zinc, silver, copper, and lead in tactite. Additional resources are in southeasterly extensions of the tactite in the Nelson adit area and on the Mike No. 2 claim, but no resource estimate could be made because the deposits are too poorly exposed.

An iron-bearing lens on the Minarets magnetite prospect (fig. 1, No. 5) west of Iron Mountain contains about 8.5 million tons (7.7 million t) of submarginal iron resources. Other smaller magnetite masses are in the vicinity but are widely scattered and thus preclude resource estimates.

North-south-trending gash fracture veins in metavolcanic rocks on the Mark prospect (fig. 1, No. 6), in the southern part of the area, contain at least 30,000 tons (27,000 t) of paramarginal silver-copper resources.

Shear zones in hornfelsic rocks on the Mono Pass claims and Bliss prospect (fig. 1, Nos. 1 and 2) contain an estimated total of 28,000 tons (25,000 t) of gold, silver, copper, lead, or zinc resources.

The geochemical survey indicated anomalous silver in a small drainage basin on the northwest side of Red Top Mountain and widespread anomalous molybdenum around its east side (fig. 1, No. 4). Limited exposures preclude estimation of the silver potential, but it is probably small. Molybdenum mineralization, as seen in numerous prospects, is insufficient to constitute a potential resource, but this does not preclude the possibility of higher grade mineralization at depth.

All of the potential resources mentioned above are in the established Minarets Wilderness except for the Minarets magnetite prospect and the Mark prospect, which are in the currently designated North Fork San Joaquin Roadless Area.

An aeromagnetic high is associated with the Minarets magnetite deposit and nearby mafic metamorphic rocks. Another anomalous magnetic high, near Mount Gibbs, has not been satisfactorily correlated with rocks exposed at the surface, and its significance is uncertain (see Chapter B). A ground magnetometer survey near prospects in the Mono Pass area (fig. 1, No. 1) revealed an anomaly that may be related to a sulfide-bearing mineralized zone, which is largely covered by glacial drift.

The study area is immediately west of the Mono-Long Valley Known Geothermal Resource Area (KGRA). Although only a small part of the study area is within the KGRA proper, the east margin of the study area is included within lands marginal to the KGRA and classified as "prospectively valuable" for geothermal resources. No recent or active volcanism occurs within the study area, however, and no features are present that might suggest anomalously high near-surface heat flow. The data, as presented in Chapter C, show that the study area has little or no geothermal potential.

Regional Setting, Geology, and Geochemical Studies of the Minarets Wilderness and Adjacent Areas, Madera and Mono Counties, California

By N. KING HUBER, U.S. GEOLOGICAL SURVEY

MINERAL RESOURCES OF THE MINARETS WILDERNESS AND ADJACENT AREAS, MADERA AND MONO COUNTIES, CALIFORNIA

GEOLOGICAL SURVEY BULLETIN 1516-A

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REGIONAL SETTING, GEOLOGY, AND GEOCHEMICAL STUDIES OF THE MINARETS WILDERNESS AND ADJACENT AREAS, MADERA AND MONO COUNTIES, CALIFORNIA

By N. King Huber, U.S. Geological Survey

INTRODUCTION

The Minarets Wilderness is situated in the east-central part of the Sierra Nevada, Calif., and includes parts of Madera and Mono Counties and parts of Sierra and Inyo National Forests (fig. 2). The officially designated Wilderness area includes approximately 170 mi^2 (440 km^2). An additional 70 mi^2 (180 km^2), designated by the U.S. Forest Service at the time of the study as the San Joaquin and North Fork San Joaquin Roadless Areas, was studied at their request. The term "study area" will be used in this report to include the entire area investigated, about 240 mi^2 (620 km^2).

LOCATION AND GENERAL CHARACTER

The Sierra Nevada is a strongly asymmetric mountain range with a long, gentle western slope and a high, steep eastern escarpment. It is 50 to 80 mi (80–130 km) wide and extends north-south through eastern California for more than 400 mi (640 km). The study area lies at the crest of the Sierra Nevada flanking the east side of Yosemite National Park; it is extremely rugged, with over 10,000 ft (3,000 m) of total relief ranging from 3,300 ft (1,000 m) where the San Joaquin River leaves the area to Mount Ritter at 13,135 ft (4,004 m). More than 25 peaks over 12,000 ft (3,660 m) in elevation lie within or on the boundary of the study area (fig. 3). The area straddles the Sierran drainage divide; the northern part drains eastward into the Mono Lake basin, and the rest of the area drains southwestward to the Great Valley via the San Joaquin River. The Ritter Range and its jagged Minarets separate the drainage basins of the North and Middle Forks of the San Joaquin River and provide some of the most spectacular alpine scenery in the United States. Another high and rugged divide separates the North Fork San Joaquin River and the Merced River drainage to the west in Yosemite National Park.

The study area is accessible by several roads (fig. 2). The Tioga Pass road through Yosemite National Park, California State Highway 120, circles the north end of the area, and the June Lake-

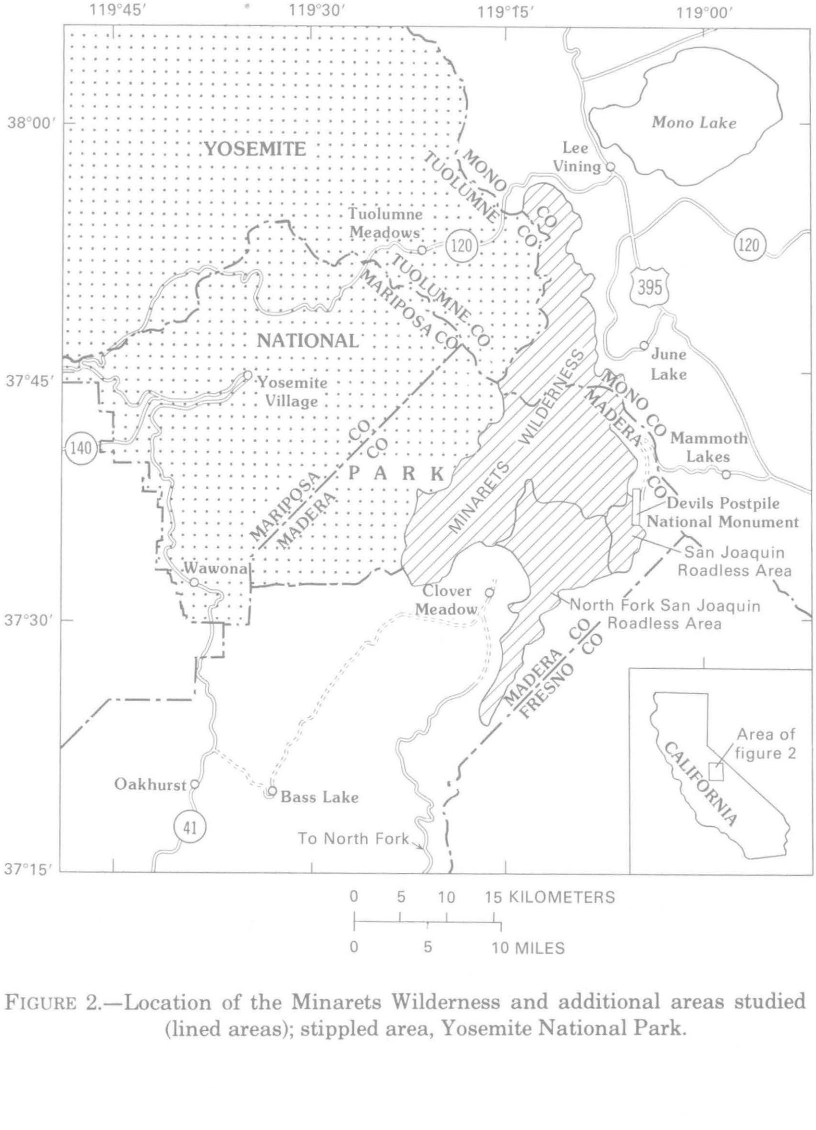


FIGURE 2.—Location of the Minarets Wilderness and additional areas studied (lined areas); stippled area, Yosemite National Park.

Grant Lake loop road, off U.S. Highway 395, provides additional access to the north part of the area, including the Rush Creek drainage. A road, paved part way, from Mammoth Lakes to Agnew Meadows, Reds Meadow, and Devils Postpile National Monument provides access to trail heads in the valley of the Middle Fork San Joaquin River. A paved road from North Fork and a graded dirt road from Bass Lake converge near Clover Meadow to provide access to the southwestern part of the study area, including the drainage basins of the North Fork San Joaquin River and Granite

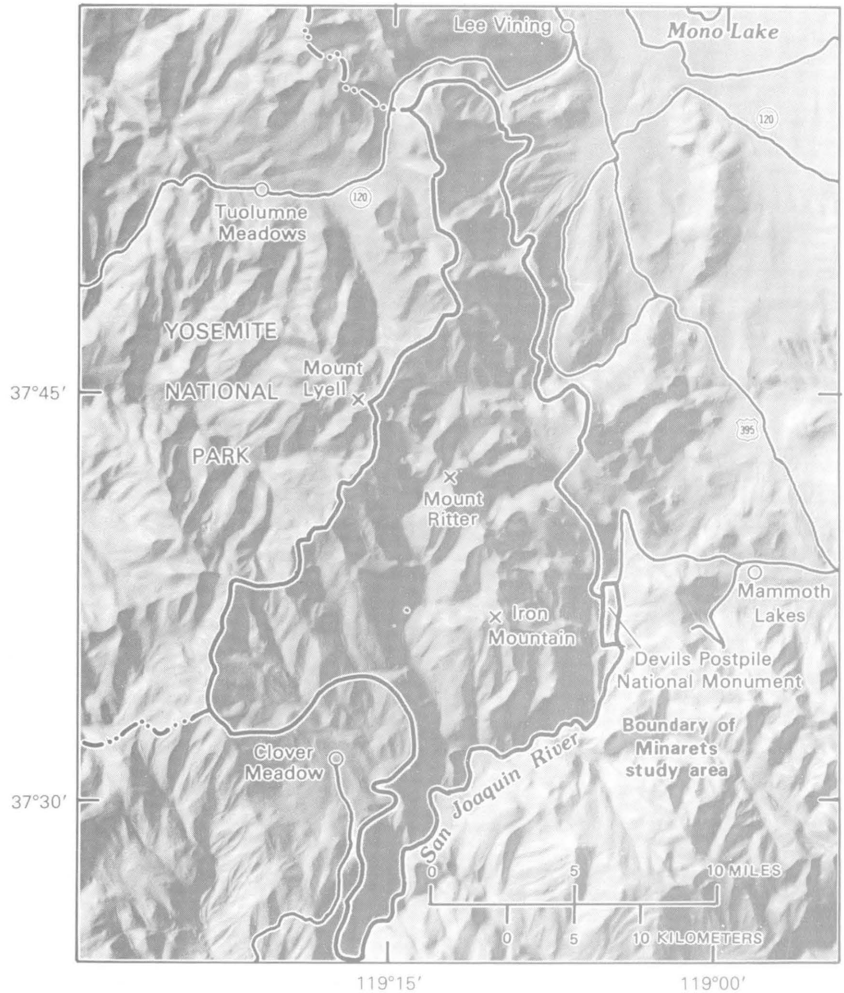


FIGURE 3.—Physiographic diagram of the Minarets study area and vicinity.

Creek and the lower gorge of the San Joaquin River. Of these, only the June Lake road is maintained during the winter.

An extensive system of improved Forest Service trails and numerous unimproved trails exists within the study area. Five improved trails enter the area from Yosemite National Park, including the John Muir trail, which crosses the Minarets Wilderness from the park boundary at Donohue Pass to Devils Postpile. Travel on foot away from the trails ranges from relatively easy in areas of subdued topography, such as in much of the Granite Creek basin, to extremely difficult in more rugged terrain, such as in much of the Ritter Range, where many of the peaks and ridges can be traversed only by properly equipped and experienced mountaineers.

The entire study area was strongly but not uniformly glaciated during Pleistocene time, creating landscapes with two different aspects. From the Rush Creek drainage south, individual glaciers coalesced to form a vast icecap with only the highest ridge crests protruding, and few areas escaped the intense glacial scouring that removed materials well down the San Joaquin River drainage. Erosional glacial features abound and contribute greatly to the spectacular scenery of this part of the High Sierra. At the heads of the glacially carved valleys are amphitheaterlike cirques, matterhorn peaks, polished and striated rock outcrops, and other scenic alpine features (fig. 4). The vast majority of the nearly 300 lakes and ponds in the study area lie within this southern block and are predominantly glacier-formed features. Only Gem and Waugh Lakes on Rush Creek are artificial reservoirs constructed as part of a hydroelectric power-generating system.

In the northern prong of the study area, north of the Rush Creek drainage, the landscape has quite a different aspect. During glaciation, individual areas of snow and ice accumulation were smaller than those to the south, and the glaciers formed in these smaller areas did not coalesce into an icecap. Rather, they flowed only short distances down steep canyons in the east-facing Sierran escarpment before dropping their load of rock debris on the floor of the Mono Lake basin, forming large elongate morainal deposits, such as those particularly well developed along Walker and Parker Creeks. Upland areas such as the Dana Plateau and the major divides and ridge spurs between the galciated canyons are mantled with frost-heaved blocks, and the aspect is one of vast talus slopes rather than glacially exposed and scoured bedrock surfaces. These differences are emphasized here because they not only make physical access to this northern area much more difficult but also distinctly hinder geologic and resource appraisal of the area.

Much of the lower elevations are forested, chiefly with pine and fir. Black oak and other leafy trees are abundant only in the deeper canyons of the San Joaquin River system. Roughly 50 percent of the study area is above timberline or supports only scattered growth because of precipitous slopes or other adverse conditions.

The winter climate of the study area is severe. The Sierra Nevada is a tremendous physical barrier that causes warm air masses passing eastward from the Pacific to rise and precipitate their moisture as snow, which is preserved as a heavy snowpack at high altitudes and in the shade of forests at lower elevations until late spring or summer. Snow-survey records indicate that the study area has among the deepest annual snowpacks in the Sierra (California Department of Water Resources, 1971), and within the area there are at least 30 small vestigial glaciers or permanent snowfields. Summers, on the other hand, are pleasant, with warm sunny days and cool nights—a delight for the wilderness visitor.

PREVIOUS INVESTIGATIONS

Prospectors and geologists have roamed the length and breadth of the Sierra Nevada since the days of the California gold rush, and there is probably no part of the range that has not been visited at least briefly, although most formal geologic studies were con-

FIGURE 4.—The Ritter Range, looking northwest from Red Top Mountain. Rugged terrain reflects glacial cirques cut into metavolcanic rock with strongly developed vertical jointing.

centrated in the "gold belt" of the western Sierra Nevada for many years. Bateman and Wahrhaftig's (1966) report reviewed much of the work that led to our present knowledge of the geology of the central Sierra Nevada and presented an extensive summary of both the bedrock geology and the Cenozoic volcanic and glacial geology of that part of the range. For the present study area the first report to provide significant geologic detail was that of Erwin (1934) on the geology and mineral resources of northeastern Madera County, centered on the Ritter Range.

More recently, the U.S. Geological Survey has published geologic maps of the five quadrangles covering the study area, mostly at a scale of 1:62,500. These geologic quadrangle maps are: Merced Peak (Peck, 1980), Devils Postpile (Huber and Rinehart, 1965a), Mono Craters (Kistler, 1966a), Shuteye Peak (Huber, 1968), and Kaiser Peak (Bateman and others, 1971). The Devils Postpile, Shuteye Peak, and Kaiser Peak quadrangle maps also included brief descriptive texts. The geologic map in this report (pl. 1) has been compiled and generalized from these sources and, in fact, could not have been produced within the available time without this earlier mapping.

Additional reports resulting from these quadrangle studies include one describing geologic structure and metamorphism in the Mono Craters quadrangle (Kistler, 1966b), two describing the Cenozoic volcanic rocks in the Devils Postpile quadrangle (Huber and Rinehart, 1965b, 1967), and one providing analytical data for the Kaiser Peak quadrangle (Bateman and Lockwood, 1970). A mineral-resource evaluation of part of Sierra National Forest by Lockwood, Bateman, and Sullivan (1972) included that part of the southernmost prong of the present study area that lies within the Kaiser Peak quadrangle. Detailed lithologic descriptions of some of the metavolcanic rocks in the Devils Postpile quadrangle were presented by Fiske and Tobisch (1978).

The glacial geology of the San Joaquin River basin was described in a reconnaissance report by F. E. Matthes (1960), and the distribution of some of the more extensive glacial deposits in the study area are shown on the geologic quadrangle maps cited.

PRESENT INVESTIGATIONS AND ACKNOWLEDGMENTS

Appraisal of the mineral resources of the study area consists of two complementary parts: a qualitative appraisal by the U.S. Geological Survey, based on the geologic setting and geochemical and geophysical surveys; and an economic appraisal by the U.S. Bureau of Mines of the mineral resources found in prospects, potential placers, or other areas of known mineralization.

Field investigations in the study area by the U.S. Geological Survey were made by me during the summers of 1973 and 1974; in 1973 I was assisted by L. D. Cress and J. K. Cannon, and in 1974 by L. D. Cress, R. D. Dockter, and R. C. Evarts. Geophysical studies of the area are interpreted by H. W. Oliver in Chapter B, and the geothermal-resource potential is discussed by R. A. Bailey in Chapter C of this volume.

Approximately 18 man-months was spent in geologic field investigations. The fieldwork was accomplished by several thousand miles (kilometers) of foot traverses through the area, with extensive use of horses and mules to establish base camps in the more remote parts of the study area. The major claims and prospects were visited by U.S. Geological Survey personnel, but the principal effort was geologic examination of the terrane and collection of samples for a geochemical evaluation of the area. More than 1,000 stream-sediment and rock samples were collected during the geochemical survey and analyzed by spectrographic, atomic-absorption, and colorimetric methods to delineate distribution patterns for selected elements.

The study benefited greatly from helpful cooperation of the staff of the Minarets district, Sierra National Forest, and of the Mammoth district, Inyo National Forest.

GEOLOGY

GEOLOGIC SETTING AND HISTORY

The Sierra Nevada is a large block of the Earth's crust that has been uplifted on the east along an extensive system of high-angle faults and tilted westward. Most of the central Sierra Nevada is composed of granitic plutons of Mesozoic age. These plutons constitute the Sierra Nevada batholith, which is part of a more or less continuous belt of plutonic rocks extending from Baja California, through the Sierra Nevada, into western Nevada. The batholith was intruded into Paleozoic and Mesozoic sedimentary and volcanic strata, which are preserved in the walls of the batholith and as roof pendants, septa, and inclusions within the batholith. Such strata, now metamorphosed, underlie nearly half of the study area, mostly in a body of rock referred to as the Ritter Range pendant (Rinehart and others, 1959). Many smaller bodies of metamorphic rock are scattered throughout the rest of the predominantly granitic terrane, particularly in the Merced Peak quadrangle in the western part of the study area.

Emplacement of the granitic rocks of the batholith was completed in Late Cretaceous time, and this episode was followed by uplift and deep erosion, culminating in late Cenozoic time with the tilted-block form of the range as we see it today. The late Cenozoic structural adjustments of the range were accompanied by volcanic activity, as indicated by erosional remnants of basalt scattered throughout the southern part of the study area and on San Joaquin Mountain ridge, and even more dramatically by the immense volcanic deposits of Long Valley and the Mono Lake basin immediately east of the study area.

METAMORPHIC ROCKS

For the purposes of this report, the metamorphic rocks are separated into only two map units: (1) a lower metasedimentary sequence of Permian(?) age, and (2) a stratigraphically higher sequence of predominantly metavolcanic rocks ranging in age from Permian to Cretaceous. The metasedimentary sequence is confined to the northern part of the study area, whereas metavolcanic rock makes up the bulk of the Ritter Range pendant and other scattered bodies of metamorphic rock.

METASEDIMENTARY ROCKS

The metasedimentary rocks exposed in the northern part of the study area consist largely of quartzofeldspathic hornfels, calc-silicate hornfels, and carbonaceous marble. These rocks are metamorphosed equivalents of siltstone, mudstone, impure quartz sandstone, and impure limestone. This sequence resembles, and is believed to be correlative with, a sequence of fossiliferous late Paleozoic strata in the Mount Morrison roof pendant, about 15 mi (25 km) to the southeast (Rinehart and Ross, 1964). The correlation is tenuous, however, and rather than attempt to extend formation names in the Mount Morrison quadrangle into the area of this report, these and related strata in the Mono Craters quadrangle have informally been referred to as the Lewis sequence (Kistler, 1966b).

One of the most common rock types in the Lewis sequence is a dark pyritic hornfels, presumably derived from a sedimentary rock rich in organic material. Oxidation of the pyrite gives the rock a rusty hue, particularly evident in the upland areas mantled by frost-shattered and -heaved rock debris, and in the extensive talus aprons descending from those areas.

The Lewis sequence has been interpreted as having undergone at least three periods of deformation (Kistler, 1966b). This deformation, together with the absence of distinctive, traceable lithologic units within the sequence, makes estimates of the stratigraphic thickness difficult. However, at least 3,300 ft (1,000 m) of strata must be present.

METAVOLCANIC ROCKS

Metavolcanic rocks, with minor interbedded metasedimentary rocks, make up the bulk of the Ritter Range pendant, and the stratigraphic section is estimated to have had an original thickness of about 50,000 ft (15,000 m) (Rinehart and others, 1959; Huber and Rinehart, 1965a; Fiske and Tobisch, 1978).

The stratigraphically lowermost part of the metavolcanic sequence within the prong of the Ritter Range pendant in the Mono Craters quadrangle has been informally referred to as the Koip sequence (Kistler, 1966b). These rocks are considered to be of Late Permian age, and they rest uncomfortably on the previously folded Lewis sequence of metasedimentary rocks. Over much of this area the two sequences are in fault contact. West of the study area the Koip sequence is uncomfortably overlain by metasedimentary and metavolcanic rocks of the Dana sequence, which is considered to be of Early Jurassic age (Kistler, 1966b).

The Koip sequence is shown as being continuous with the lower part of the metavolcanic sequence in the Devils Postpile quadrangle to the south (pl. 1). The age relations are uncertain, however, and some of the rock types in the Koip sequence, particularly the metasedimentary rocks, are not present to the south. An unconformity, such as that between the Koip and Dana sequences, also has not been recognized to the south.

In the Devils Postpile quadrangle, as to the north, the metavolcanic sequence lies with probable unconformity on late Paleozoic metasedimentary rocks. Fossils of Early Jurassic age occur near Garnet Lake in a narrow belt of calcareous rocks, approximately 10,000 ft (3,000 m) stratigraphically above the base of the metavolcanic sequence (Rinehart and others, 1959). Radiometric-age data (Fiske and Tobisch, 1978) indicate that some of the uppermost metavolcanic rocks are Cretaceous.

The metavolcanic rocks are predominantly felsic to intermediate pyroclastic or fragmental types. In much of the central part of the Ritter Range pendant the metamorphism is so slight that primary rock textures are well preserved, and the origin of the volcanic rocks can readily be deduced. The pyroclastic rocks are interlayered with less common mafic lava flows and cut by hypabyssal intrusions. Thin beds of epiclastic rocks are scattered throughout the metavolcanic sequence, and several thin beds of limestone (now impure marble) have been mapped east of the Ritter Range (pl. 1).

The smaller masses of metavolcanic rocks in the western part of the study area are of a higher metamorphic grade and consist of quartz-feldspar-mica hornfels, amphibolite hornfels, and less abundant schist and gneiss. They, too, have been interpreted as being derived largely from pyroclastic volcanic rocks of intermediate composition and less common mafic lava flows (Peck, 1980).

PLUTONIC ROCKS

DIORITE, QUARTZ DIORITE, AND GABBRO

Fine- to coarse-grained diorite, quartz diorite, and gabbro occur as generally small scattered masses throughout the study area. The origin of these mafic rocks is somewhat of an enigma and is probably not the same for all masses included in this category. Some are probably plutonic rocks, whereas others may be strongly recrystallized mafic metamorphic rocks. Their age probably varies, although they all appear to be older than the granitic plutons of Late Cretaceous age.

GRANITIC ROCKS

The Sierra Nevada batholith is composed of numberous of individual plutons of granitic rock that were emplaced during a long period—more than 100 m.y.—beginning in the Triassic and ending in the Late Cretaceous (Evernden and Kistler, 1970). The granitic rocks within the study area are considered to be part of this composite batholith, and rocks of at least 10 different plutons covering the entire age span are present.

Most of these granitic rocks are Late Cretaceous, 79 to 90 million years (m.y.) old (Evernden and Kistler, 1970), and are not further differentiated on plate 1. The major plutons included in this category are the granodiorite of Jackass Lakes in the western part of the map area (Peck, 1980), the Mount Givens Granodiorite in the southern part of the map area (Huber and Rinehart, 1965a; Huber, 1968; Bateman and others, 1971), rocks similar to the Cathedral Peak Granite in the vicinity of Devils Postpile (Huber and Rinehart, 1965a), and the granodiorite of Kuna Crest in the Rush Creek, Thousand Island Lake, and Garnet Lake basins (Huber and Rinehart, 1965a; Kistler, 1966a). These rocks include both granodiorite and quartz monzonite; the granodiorite probably is slightly more abundant. The granodiorites commonly have an indistinct primary foliation, indicated chiefly by preferred orientation of mafic inclusions, although all these granitic rocks tend to be massive and commonly form bold rounded outcrops.

In contrast to the younger plutonic rocks, a belt of granitic rocks extending along the northeast side of the study area, from the Tioga Pass road to a point south of Silver Lake, is considered to be Triassic, 195 to 210 m.y. old (Evernden and Kistler, 1970), representing the oldest intrusive episode in the Sierra Nevada. These older granitic rocks have undergone extensive deformation, are closely jointed, and commonly form rubbly outcrops with extensive talus aprons. A small body of granitic rock west of Gem Lake is also considered to be of the same age because of pervasive secondary structures imposed on it (Kistler, 1960).

Three other small granitic units that intrude Jurassic metavolcanic rocks are older than the main body of late Cretaceous batholithic rocks. One unit, about 4 mi^2 (10 km^2) in area, makes up most of the ridge between the King Creek and Minaret Creek drainages. For ease of reference we will refer to this unit as the granodiorite of Lost Dog Lake, although quartz monzonite is nearly as abundant. This granodiorite previously had been considered a part of a large Late Cretaceous pluton mapped as "rocks similar to the Cathedral Peak Granite" (Huber and Rinehart, 1965a), but field observations during the present study suggest that it is an older body of rock truncated the Cathedral Peak-type rock. This conclusion is supported by a potassium-argon age determination on a sample of the granodiorite of Lost Dog Lake from near Minaret Creek (table 1). The ages determined for coexisting biotite and hornblende are discordant—78.3 m.y. for the biotite and 85.2 m.y. for the hornblende. The biotite age is the same as the average age (78 m.y.) for the adjacent Cathedral Peak-type rocks (Evernden and Kistler, 1970). However, biotite loses argon more readily than hornblende when both are heated by an adjacent intrusion (Hart, 1964), and the significantly older hornblende age is taken as a minimum for that of the granodiorite of Lost Dog Lake. This age distinction is important because only the older of the granitic rocks in the study area locally appear to have

TABLE 1.—*Potassium-argon age determinations, granodiorite of Lost Dog Lake*
[Potassium measurements by Lois Schlocker. Argon measurements and age calculations by R. W. Kistler]

Specimen number	Mineral	K_2O (wt. percent)	$^{40}Ar^{rad}$ ($\times 10^{-11}$ mol/g)	$^{40}Ar^{rad}$ (percent)	Age (m.y.)
5K091	Biotite	8.94 8.97	105.66	72	78.3±2.1
5K091	Hornblende	1.011	13.005	50	85.2±2.2

Constants: $\lambda_\beta = 4.72 \times 10^{-10}$ year^{-1};
$\lambda_\epsilon = 0.584 \times 10^{-10}$ year^{-1};
1.19×10^{-4} atoms ^{40}K/atoms K.

been mineralized to any significant degree; the rocks still considered to be part of the Cathedral Peak-type rock show no signs of mineralization.

Deformational stresses that did not affect the Cathedral Peak-type rock caused local shearing, accompanied by emplacement of aplite dikes, in the granodiorite of Lost Dog Lake and shattered the rock to form a closely spaced joint system. It is conceivable that these deformational stresses were related to the emplacement of Cathedral Peak. Quartz with minor mica and pyrite was introduced along the joints, and oxidation of the pyrite and precipitation of iron oxides on joint surfaces give much of the outcrop area of this rock a reddish-brown hue. On freshly broken surfaces, however, the rocks are relatively unstained.

A small second unit of granitic rocks, termed the granodiorite of King and Fish Creeks (Huber and Rinehart, 1965a), occupies about 3 mi^2 (8 km^2) just west of the granodiorite of Lost Dog Lake, an area of similar size near Lion Point, and a small patch southeast of Cargyle Meadow. The age of this granodiorite is unknown, but it appears to be cut by Cathedral Peak rocks and the Mount Givens Granodiorite, both of Late Cretaceous age (Huber and Rinehart, 1965a). The granodiorite of King and Fish Creeks contains many metavolcanic inclusions, including much partly to nearly completely assimilated material. Local shearing is evident, and numerous mafic and rhyolitic dikes are present.

A third small granitic unit, termed the quartz monzonite of Shellenbarger Lake (Huber and Rinehart, 1965a), occupies about 5 mi^2 (13 km^2), largely in the Dike Creek and Iron Creek basins and southwest of Iron Mountain. This quartz monzonite has a rather unusual texture for plutonic rocks in this part of the Sierra Nevada, commonly containing albite phenocrysts in a micrographic groundmass (termed "micro-pegmatitic granite" by Erwin (1934)). Like the granodiorite of Lost Dog Lake, the quartz monzonite of Shellenbarger Lake has been subjected to a deformational stress that has locally shattered the rock, and joint surfaces of the quartz monzonite are similarly stained with rusty-hued iron oxide. The quartz monzonite of Shellenbarger Lake is truncated by and thus is older than the Late Cretaceous Mount Givens Granodiorite.

VOLCANIC ROCKS

Basalt flows and cinder deposits are scattered throughout the south-central part of the study area. Many of them are late Pliocene, about 3 to 3.5 m.y. old (Dalrymple, 1964), and occur as erosional remnants on a rolling upland surface at intermediate elevations. They are most abundant in the areas around Cora

Lakes, Snake and Corral Meadows, and Granite Stairway. Basalt at Devils Postpile, on the other hand, lies at the bottom of the canyon of the Middle Fork San Joaquin River and was erupted during one of the Pleistocene interglacial epochs (Huber and Rinehart, 1965b, 1967).

A thick sequence of basalt flows and interbedded cinder deposits, overlain by pyroclastic deposits and flows of more felsic composition, makes up much of the ridge capped by San Joaquin Mountain at the east edge of the study area. All these rocks are late Pliocene, about 3 m.y. old (Dalrymple, 1964; Curry, 1966), and represent an early phase of the extensive volcanic activity that took place in Long Valley and the Mono Lake basin, immediately east of the study area, beginning at least as early as the late Pliocene and continuing into the Holocene.

UNCONSOLIDATED DEPOSITS

Most of the unconsolidated deposits in the study area consist of talus aprons at the base of steep slopes and thin veneers of slopewash on the gentler hillsides. Except for the north end of the area, north of Alger Lakes, such surficial deposits are of limited thickness and extent, and bedrock is exposed over most of the area.

Stream channels generally are filled with coarse unsorted gravel, but finer alluvium occurs in places where gradients are low. Pumice, derived from explosive volcanic activity east of the study area, is generally present in alluvium and slope wash east of the Ritter Range but is abundant only on the upper slopes of the San Joaquin Mountain ridge.

The study area is generally characterized as one of glacial erosion rather than deposition, although deposits of glacial till occur as prominent lateral moraines of Wisconsinan age along the lower reaches of Gibbs, Walker, and Parker Creeks in the north. Fairly extensive morainal deposits are also present in the Cargyle Creek drainage in the southern part and the Granite Creek drainage in the western part of the study area.

STRUCTURE

The stratigraphic units that make up the section of metamorphic rocks in the Ritter Range pendant within the study area have an average strike of about N. 30° W. and for the most part have been tilted into a near-vertical position. The oldest rocks are on the east, and the section becomes progressively younger to the west. In spite of this apparent simplicity of structure, the metamorphic rocks in the northern part of the study area have been moderately to tightly folded, particularly the metasedimentary rocks of the Lewis sequence. Folding in the central part of the Ritter Range pendant is generally weak, but moderately tight folds are present in places, especially in areas adjacent to granitic intrusions, such as near Garnet and Thousand Island Lakes and the upper Rush Creek basin.

All the metamorphic rocks and the older granitic rocks are strongly jointed, possibly as a result of deformational stress imposed during intrusion of the youngest (Late Cretaceous) plutonic rocks. Minor faulting in the metamorphic rocks probably represents structural adjustment during this same deformation, although few major throughgoing faults have been mapped within this part of the tilted Sierra Nevada structural block.

Faults are more abundant in the northern part of the study area, particularly in the Mono Craters quadrangle, because of displacement related to the development of the eastern Sierra escarpment. The range-front fault that extends along the east side of the study area from Lee Vining Canyon to a point south of Silver Lake is estimated to have had vertical displacement of about 1,000 ft (300 m) since the Sherwin glaciation occurred between ¾ and 1 m.y. ago (Kistler, 1966b).

MINERAL RESOURCES

The study area is within a region where gold and other metals have been sought extensively, beginning at least as long ago as the mid-1800's and accelerated by the discovery of gold in the Mammoth district, east of the study area, about 1878. Many local mineralized areas are present, and more than 1,000 mining claims have been filed, chiefly for gold, copper, lead, zinc, silver, molybdenum, tungsten, and iron.

GEOLOGIC SETTING OF METALLIC-MINERAL OCCURRENCES

With few exceptions, the known occurrences of mineralized zones are confined to the metamorphic rocks; the exceptions appear to be confined to plutonic rocks that are older than the late Cretaceous granitic rocks which make up the bulk of the batholithic rocks in the study area. The mineralization thus appears to predate or perhaps be contemporaneous with the intrusion of the younger plutons.

The most extensive mineralized area within the metamorphic rocks consists of scattered replacement deposits of Cu-Pb-Zn sulfides in a narrow belt of impure limestone interbedded with volcaniclastic rocks of the Ritter Range pendant. This belt is exposed almost continuously for about 3 mi (5 km) from a point just north of Minaret Creek northwest across Volcanic ridge and Shadow Creek to the west end of Garnet Lake (pl. 1). A second parallel belt of impure limestone, or calcareous tuff, about 1¼ mi (2 km) to the east does not appear to be mineralized.

Other base-metal deposits in the metamorphic rocks appear to be structurally localized and occur as widely scattered small pods of sulfide and gangue minerals along fractures, regional joints, or faults, as at the Bliss prospect in the upper basin of the North Fork of the San Joaquin River. Base-metal sulfides also occur in quartz veins or pods along Alger Creek and at Mono Pass, and adjacent to a felsic dike in Glacier Canyon near Dana Lake. Most of these base-metal deposits contain some silver.

At the Mark prospect, on the east side of Green Mountain, copper in the form of chalcocite and bornite occurs as very fine grains disseminated in equally fine grained metatuff. Locally the sulfide minerals have been remobilized and occur as thin stringers and irregular masses along fractures crosscutting the bedded tuff.

The Minarets magnetite deposit, just west of Iron Mountain, consists of massive magnetite and actinolite in metavolcanic rocks near their contact with an intrusion of quartz monzonite of Shellenbarger Lake. Magnetite-bearing veinlets also cut the quartz monzonite.

Within the intrusive rocks, base-metal minerals occur in the quartz monzonite of Shellenbarger Lake, particularly in the upper drainage of Iron Creek and in the granodiorite of Lost Dog Lake south of Minaret Creek. Silver and molybdenum also occur in the mineralized areas in the granodiorite of Lost Dog Lake. A few small scattered occurences of base-metal minerals are in the granodiorite of King and Fish Creeks.

The Strawberry tungsten mine, on the West Fork of Granite Creek about 2 mi (3 km) northwest of the Clover Meadow Ranger Station, lies about 1 mi (1.5 km) outside of the southwestern part of the study area. The geology of the Strawberry mine was investigated by Trengove (1949) and by Krauskopf (1953). Subsequently, the general area was mapped by Peck (1964) as part of his studies of the Merced Peak quadrangle, and more detailed studies of the mine area itself were undertaken by Nokleberg (1981a, b). The tungsten occurs in a scheelite-bearing tactite in calcareous hornfels layers within a sequence of metasedimentary rocks consisting chiefly of quartz mica schist, micaceous quartzite, and minor marble. All of the mapping indicates that the metasedimentary rock sequence that is host to the tungsten mineralization does not extend into the present study area.

The only productive gold deposits in the general vicinity of the study area occur near Mammoth Lakes, approximately 5 mi (8 km) east of the study-area boundary. The deposits are within a strongly altered zone in a metamorphosed latite referred to as the latite of Arrowhead Lake (Rinehart and Ross, 1964). Most of this geologic unit consists of intrusive, hypabyssal latite, but it also includes some tuff and possibly some flows, as well as a few lenses of metasedimentary rock. The altered zone contains abundant disseminated pyrite, much of which has been oxidized and has stained the entire zone bright reddish brown, which strongly contrasts with the surrounding unaltered gray rocks. The latite of Arrowhead Lake has not been recognized within the present study area.

GEOCHEMICAL STUDIES

The main objective of the geochemical survey was to identify areas that possibly contain undiscovered or concealed mineral deposits which might be economically exploited in the future. More than 1,000 samples, mostly of stream sediments, were collected, analyzed, and evaluated in terms of their metallic content and geologic environment. The sample locations are shown on plate 2. In addition, analyses of nine sediment samples and more than a hundred rock samples were available from other work in or adjacent to the study area.

SAMPLING AND ANALYTICAL PROCEDURES

Sediment samples were taken from all the major streams and tributaries, including some samples from streams outside the study area that headed within or crossed the study area. Particular care was taken to obtain samples above the junctions of tributaries and main streams, and effort was made to obtain a sample density of about 2 samples per square kilometer. Although this general sample density was achieved for the study area as a whole, in certain areas, such as in parts of the Ritter Range, the rushing mountain torrents contained virtually no fine sediment for long stretches. Coverage in the northernmost part of the study area is particularly spotty because most rain and snowmelt water in that area percolates down through vast talus deposits, and sediment samples can only be obtained in a few of the major creek bottoms. Wherever possible, about a cupful of the finest grained sediment free of visible organic material was collected. The samples were later dried and sieved, and the fraction finer than 80 mesh was analyzed.

Rock samples also were collected to provide geochemical background data for the various major rock types (in conjunction with analytical data from other sources) to help evaluate the stream-sediment data. Although the geochemical survey included some samples of altered or mineralized rock, most rock samples from claims, prospects, and other obviously mineralized areas were obtained during individual study of such areas by U.S. Bureau of Mines personnel and are described and discussed in chapter D of this volume.

All the geochemical samples were analyzed for 30 elements (table 2) by semiquantitative six-step spectrographic analysis. Most of the sediment samples were also analyzed by colorimetric methods for citrate-extractable copper (CxCu) and heavy metals (CxHM) (includes copper, lead, zinc, and cobalt, reported as equivalent zinc) to determine the quantity of weakly held metals absorbed from stream water by the clay fraction of the sediment. In addition, the sediments were analyzed for gold and zinc by atomic-absorption methods, which have a lower limit of detection than the spectrographic analysis. All analytical methods were similar to those described by Ward and others (1963, 1969), and Grimes and Marranzino (1968). The analyses were made in mobile field laboratories and at the U.S. Geological Survey laboratories in Denver, Colo. Analysts were E. F. Cooley, W. D. Crim, C. A. Curtis, G. W. Day, M. S. Erickson, J. G. Frisken, D. J. Grimes, J. D. Hoffman, R. T. Hopkins, V. D. James, J. M. Motooka, R. M. O'Leary, J. D. Sharkey, D. F. Siems, and C. L. Whittington. The analytical data are reported in percent for a few of the major elements (Fe, Mg, Ca, Ti) and in parts per million (ppm) for the rest. For the convenience of the reader, table 3 is included to facilitate the conversion of parts per million to percent and to ounces per ton, and vice versa. The analytical methods used do not produce true assay values. Results from the spectrographic analyses, for example, are reported to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, and so on, which represent approximate

TABLE 2.—*Elements determined by spectrographic analysis and their lower limits of determination (ppm)*

Antimony	100	Copper	5	Scandium	5
Arsenic	200	Gold	10	Silver	0.5
Barium	20	Iron	500	Strontium	100
Beryllium	1	Lanthanum	20	Tin	10
Bismuth	10	Lead	10	Titanium	20
Boron	10	Magnesium	200	Tungsten	50
Cadmium	20	Manganese	10	Vanadium	10
Calcium	500	Molybdenum	5	Yttrium	10
Chromium	10	Neodymium	20	Zinc	200
Cobalt	5	Nickel	5	Zirconium	10

midpoints of group data on a geometric scale; they are generally within 30-60 percent of the correct value. Such analyses have proved useful for reconnaissance exploration purposes. For a few principal metals, other, more accurate laboratory assays of the U.S. Bureau of Mines samples additionally were used to evaluate the economical potential of the individual prospects studied.

Although all the geochemical data were reviewed and evaluated during this resource appraisal, for reasons of space only those data considered to indicate anomalous metal concentrations or otherwise to be essential to discussion of the resource appraisal are presented in this report. All the geochemical data are available separately on magnetic tape from the U.S. Department of Commerce, National Technical Information Service (NTIS), Springfield, VA 22151, at the expense of the user (see Whittington and others, 1978).

EVALUATION OF GEOCHEMICAL SAMPLE DATA

Stream-sediment samples represent a composite of the material upstream from the sample site, and therefore each one represents a considerable area. Stream-sediment sampling can be a powerful and rapid method of mineral exploration, inasmuch as anomalous quantities of a metal in the sediments may signal the occurrence of concealed or unknown deposits of prospecting interest. Stream-sediment geochemistry is a direct means of excluding territories of

TABLE 3.—*Conversion of parts per million to percent and to troy ounces per ton and vice versa*

[Conversion factors: 1 pound avoirdupois = 14.583 troy ounces: 1 ppm = 0.0001 percent = 0.0291667 troy ounce per short ton = 1 gram per metric ton; 1 troy ounce per ton (Au or Ag) = 34.286 ppm = 0.0034286 percent]

Parts per million to percent to ounces per ton			Ounces per ton to percent to parts per million		
ppm	Percent	Ounces per ton	Ounces per ton	Percent	ppm
0.01	0.000001	0.0003	0.01	0.00003	0.3
.02	.000002	.0006	.02	.00007	.7
.05	.000005	.0015	.05	.00017	1.7
.10	.00001	.003	.10	.00034	3.4
.20	.00002	.006	.20	.00069	6.9
.30	.00003	.009	.30	.00103	10.3
.40	.00004	.012	.40	.00137	13.7
.50	.00005	.015	.50	.00171	17.1
.60	.00006	.017	.60	.00206	20.6
.70	.00007	.020	.70	.00240	24.0
.80	.00008	.023	.80	.00274	27.4
.90	.00009	.026	.90	.00309	30.9
1.0	.0001	.029	1.0	.00343	34.3
10.0	.001	.292	10.0	.03429	342.9
20.0	.002	.583	20.0	.06857	685.7
50.0	.005	1.458	50.0	.17143	1,714.0
100.0	.01	2.917	100.0	.34286	3,429.0
500.0	.05	14.583	500.0	1.71	17,143.0
1,000.0	.10	29.167	1,000.0	3.43	34,286.0
10,000.0	1.00	291.667	10,000.0	34.29	342,857.0

little promise from those areas with more than average promise, thus directing the exploration effort into areas of maximum interest. The absolute chemical values for the samples are not so important as are anomalies with reference to the overall area and the geologic environment (Brown, 1971). The threshold values beyond which analytical results from the sediments are to be considered anomalous will vary from one geologic environment to another, depending on the general background values for any given element in the particular rock type involved.

Evaluation of the stream-sediment data in the area is complicated by the wide diversity of rock types present, even within relatively small drainage basins. Ideally, it would be desirable to isolate and compare analytical data by individual drainage basins or bedrock types in trying to determine which values are anomalous. In practical terms, however, the problem of geologic diversity is lessened by the fact that the great bulk of the metavolcanic rocks in the Ritter Range pendant are of intermediate to felsic composition and thus do not differ greatly from the granitic rocks. The only igneous rocks in the study area that are significantly different are the late Pliocene and Pleistocene basalt.

Two different approaches were used for evaluating the geochemical data. For those elements that were detected in a relatively small percentage of the samples (gold, silver, tin, tungsten), all detected amounts were considered anomalous, and the distribution of all these samples is shown on the illustrations in this report. For elements with higher concentration, as indicated by their detection in most if not all of the samples, all data were statistically examined in an attempt to determine what might be the expected distribution for individual elements in the entire data set and to establish a threshold value for data to be considered anomalous. Data considered to be anomalous can then be looked at with respect to the geologic environment whence they came in an attempt to determine their significance.

Threshold values in geochemical data have been chosen in a variety of ways by different workers. Almost all elements have a log-normal distribution in geologic materials (Ahrens, 1957; Siegel, 1974), particularly the less abundant elements, whose concentrations may result in a mineral deposit. In this study a simplified statistical treament of geochemical data by graphical representation (Lepeltier, 1969; Sinclair, 1974) was used to search for departures from a log-normal distribution in a data set in an attempt to determine the threshold value for anomalous data. This method involves plotting the frequency distribution on log-probability graphs. Departure from a straight line on such a graph indicates departure from a log-normal distribution. If such departures are not found, it is common to consider values more than two standard deviations greater than the geometric mean as being potentially anomalous (Lepeltier, 1969; Siegel, 1974). Two examples using data from this study are presented to illustrate the method and possible interpretation of the results.

The frequency distribution for lead has a significant positive flexure on the curve indicating a skewness toward the high end of the data set (fig. 5). The flexure occurs at about 70 ppm, and as this value is less than two standard deviations from the geometric mean, it is taken as the threshold value. This method of selecting a threshold for an element is based on the concept that an ore deposit is a local, generally highly variable anomalous concentration of a particular element superimposed on a less variable background abundance of that element in the country rock.

The straight-line segment to the left of the flexure is taken to

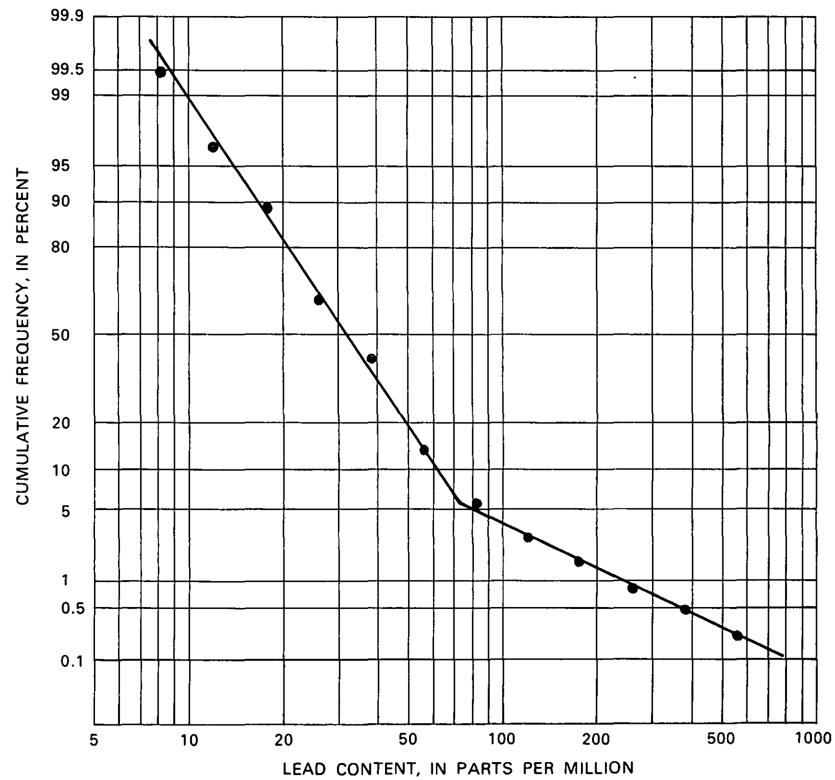


FIGURE 5.—Cumulative frequency distribution for lead in stream-sediment samples.

represent the background population, and the segment to the right an anomalous departure from the background. Values at the threshold can be either at the high end of the background population or at the low end of the anomalous population, but are here included with the latter to decrease the chance of ignoring significant data. Of the elements examined in detail in this report (table 4), Cu, Pb, Zn, and V have data curves of this type.

The frequency distribution for nickel (fig. 6), rather than showing a simple positive flexure, occurs as two straight-line segments, which are interpreted as indicating a tendency toward a bimodal distribution rather than a simple skewness for the data set as a whole. This bimodal distribution suggests the mixing of two separate data populations, each with its own log-normal distribution. The two populations could indicate local mineralization strong enough to show up as a separate population superimposed upon the background, rather than simple skewness; or it could simply represent the influence of two distinct rock types, that is, two background populations. The distribution of the analytical data must be compared to the geologic setting where the individual samples were collected to determine which of these possibilities is most likely. In the case of nickel, as will be demonstrated later, two different rock types define the shape of the frequency distribution curve. The absence of a positive flexure at the high-value end of the plot suggests the absence of anomalous nickel beyond that associated with the rock types having the higher population values. In

TABLE 4.—*Elements used for the selection of anomalous samples, their threshold values, and numbers and percentages of samples at or above threshold*

Element	Analytical method[1]	Lower limit of detection (ppm)	Threshold value (ppm)	Anomalous samples	
				Total number	Percent of samples analyzed
Ag	S	0.5	0.5	80	8.8
Au	AA	0.05	0.05	12	1.3
B	S	10	70	50	5.5
Cr	S	10	70	104	11.4
Cu	S	5	50	98	10.8
CxCu	CM	1	10	44	5.0
Mo	S	5	20	36	4.0
Ni	S	5	30	126	13.9
Pb	S	10	70	123	13.6
Sn	S	10	10	5	0.6
V	S	10	200	43	4.7
W[2]	S	50	50	9	1.0
Zn	AA	5	70	115	12.7
CxHM	CM	1	9	52	5.9

[1]S, spectrographic; AA, atomic absorption; CM, colorimetric.
[2]Three samples determined by AA with lower limit of 20 ppm (3, 4, 5 on fig. 14).

the case of molybdenum, which has a bimodal plot similar to that for nickel, geologic analysis indicates that the distribution represents mineralization superimposed on a more or less single lognormal population.

For purposes of analysis, the threshold value for plots of this type is taken as the midpoint of a connecting line segment (Lepeltier, 1969), and for nickel (fig. 6) has a value of about 30 ppm. Of the elements examined in detail in this report, B, Cr, Mo, Ni, and CxHM have data curves of this type.

Graphical analysis of the geochemical data indicates that 12 of the elements determined, along with citrate-extractable copper and heavy metals, show anomalous values of potential interest (this includes the four elements for which all values above the lower detection limit are considered anomalous—Ag, Au, Sn, and W). The threshold values determined for each of these elements,

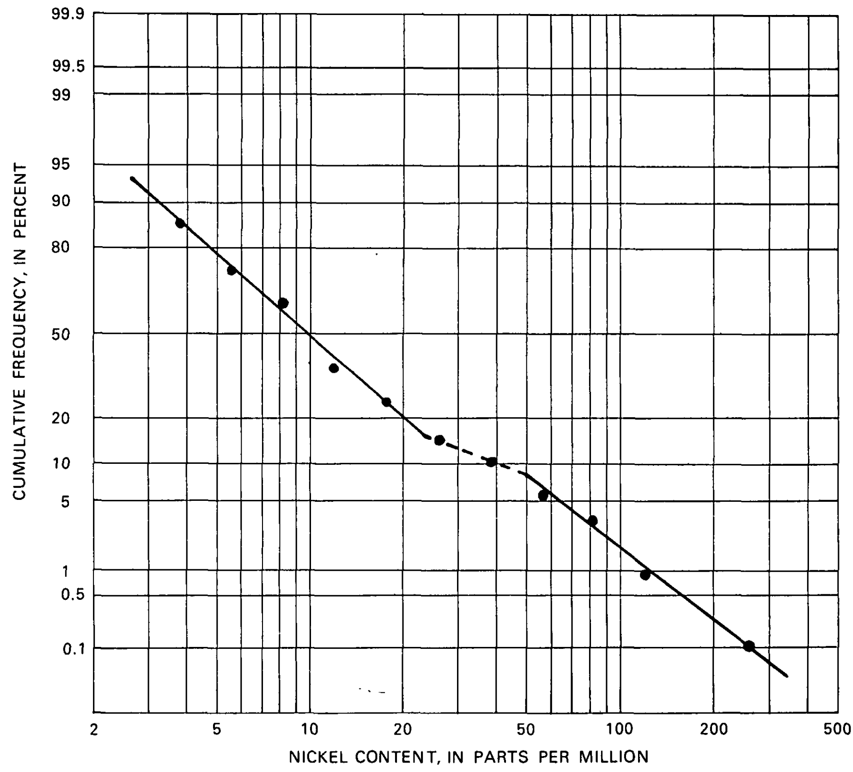


FIGURE 6.—Cumulative frequency distribution for nickel in stream-sediment samples.

and the number and percentage of samples involved, are listed in table 4. The geographic distribution of the anomalous samples, by element, is shown in figures 7 through 19 and discussed in the following sections.

MINERAL COMMODITIES

COPPER, LEAD, AND ZINC

Base-metal sulfide minerals are the most widespread form of metallic mineralization in the study area, as is clearly reflected in the analytical data for the stream-sediment samples. Virtually all samples with significantly anomalous amounts of copper, lead, or zinc are anomalous in two or all three of these elements, and most of the major areas with anomalous base metals also contain anomalous silver (figs. 7–11).

All of the major base-metal/silver anomalies, those indicated by multiple samples in the higher part of the anomalous range, are downstream from or within areas of visible sulfide mineralization, and virtually all of them have been extensively prospected. The less well defined anomalies generally can be related to smaller mineralized areas, most of which also contain prospect pits. Anomalous values of citrate-soluble copper and heavy metals point to the same mineralized areas as the spectrographic copper and spectrographic zinc, respectively.

It is noteworthy that all major anomalies of copper, lead,and zinc identified in this survey are associated with areas previously known to be mineralized, which is not especially surprising in a region as well exposed and extensively prospected as the study area. It is possible, of course, that the anomalous samples reflect larger areas of low-grade mineralization than individual prospects might indicate.

Although it is possible that some areas containing scattered copper-lead-zinc minerals have been overlooked, the Mark copper prospect is the only known deposit of any significance whose presence is not reflected by the geochemical survey. This prospect, on the east side of Green Mountain, is on a bench above the North Fork San Joaquin River with no coherent drainage pattern down to that river for the collection of sediment samples.

In summary, the areas indicated by the geochemical survey as having significant anomalous values of base metals and silver, listed from north to south on the east and west sides of the study area, are:

(1) Dana Lake area, Glacier Canyon
(2) Kidney Lake area, Gibbs Canyon

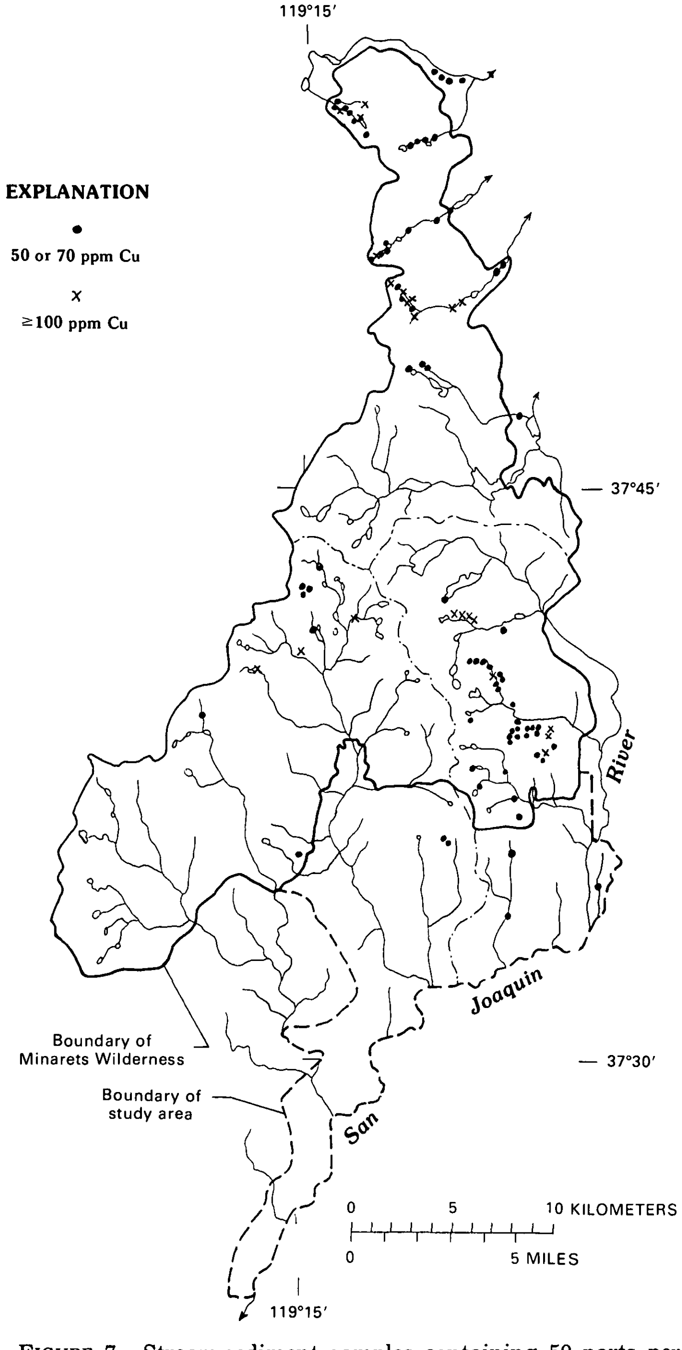


FIGURE 7.—Stream-sediment samples containing 50 parts per million (ppm) or more copper (Cu) in and near the Minarets study area.

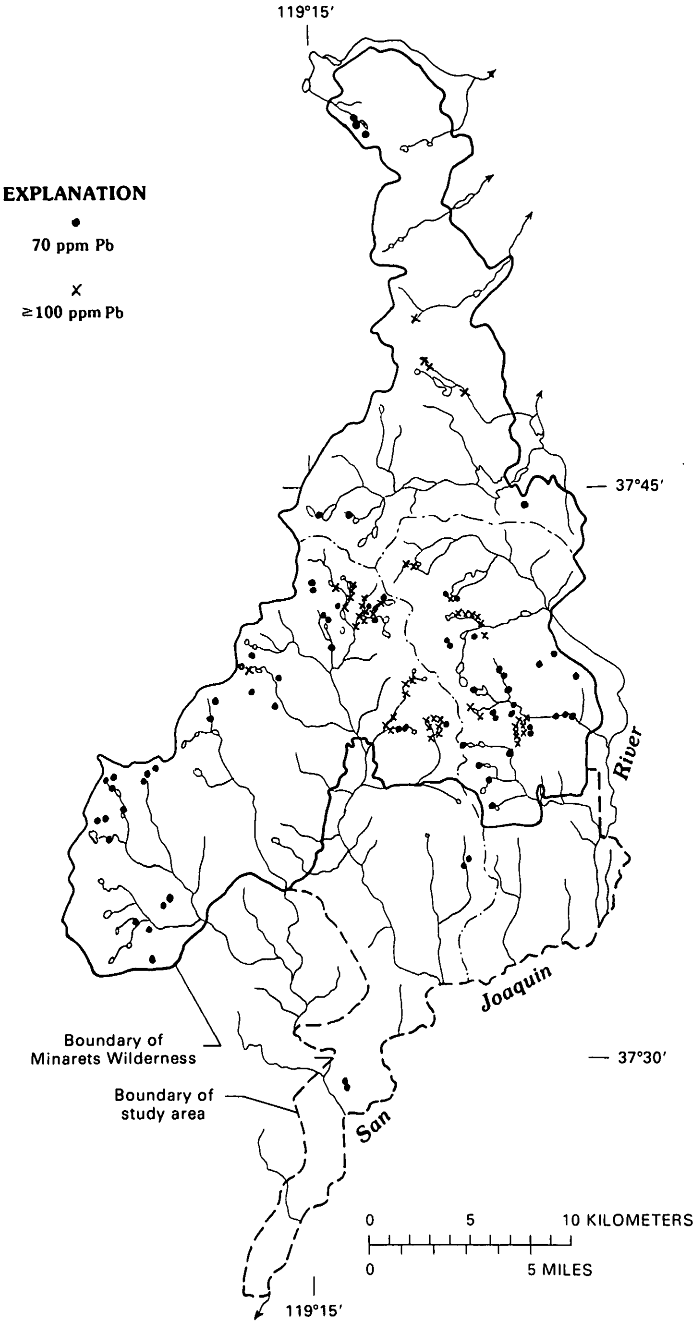


FIGURE 8.—Stream-sediment samples containing 70 parts per million (ppm) or more lead (Pb) in and near the Minarets study area.

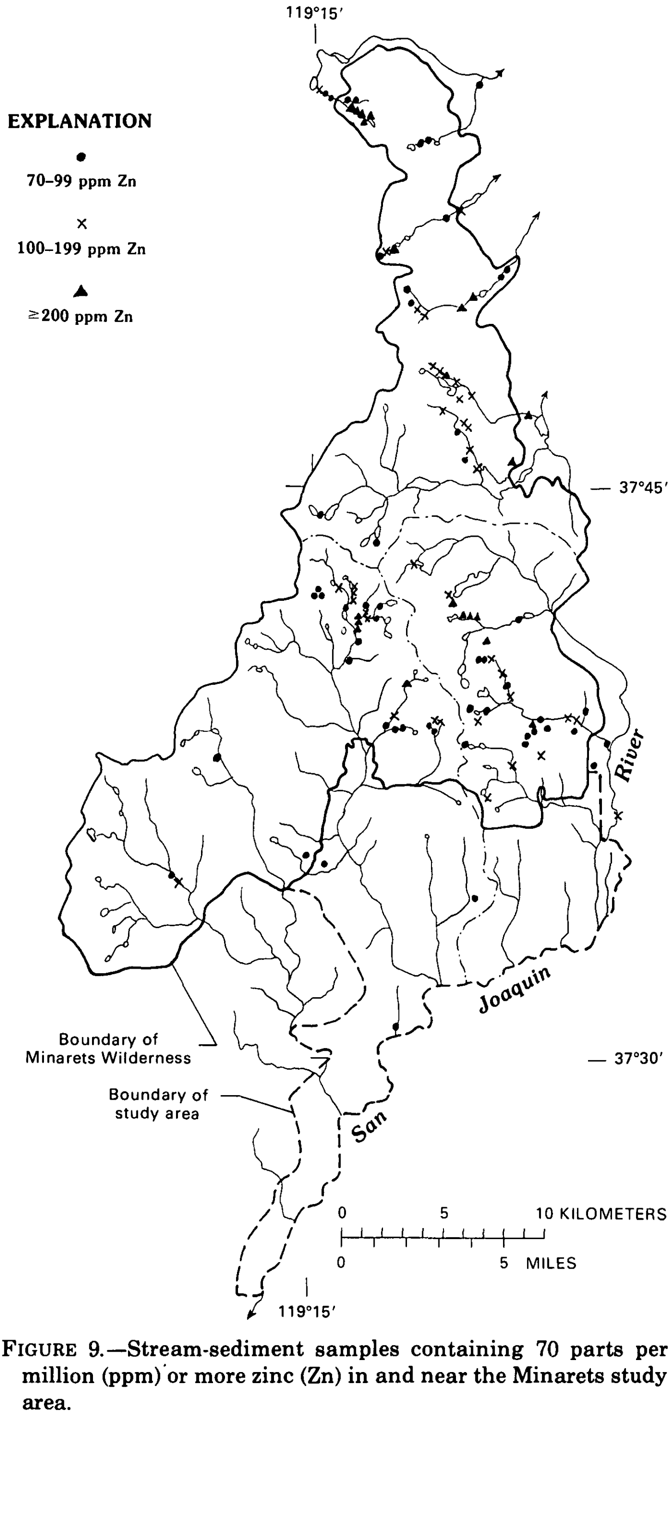


FIGURE 9.—Stream-sediment samples containing 70 parts per million (ppm) or more zinc (Zn) in and near the Minarets study area.

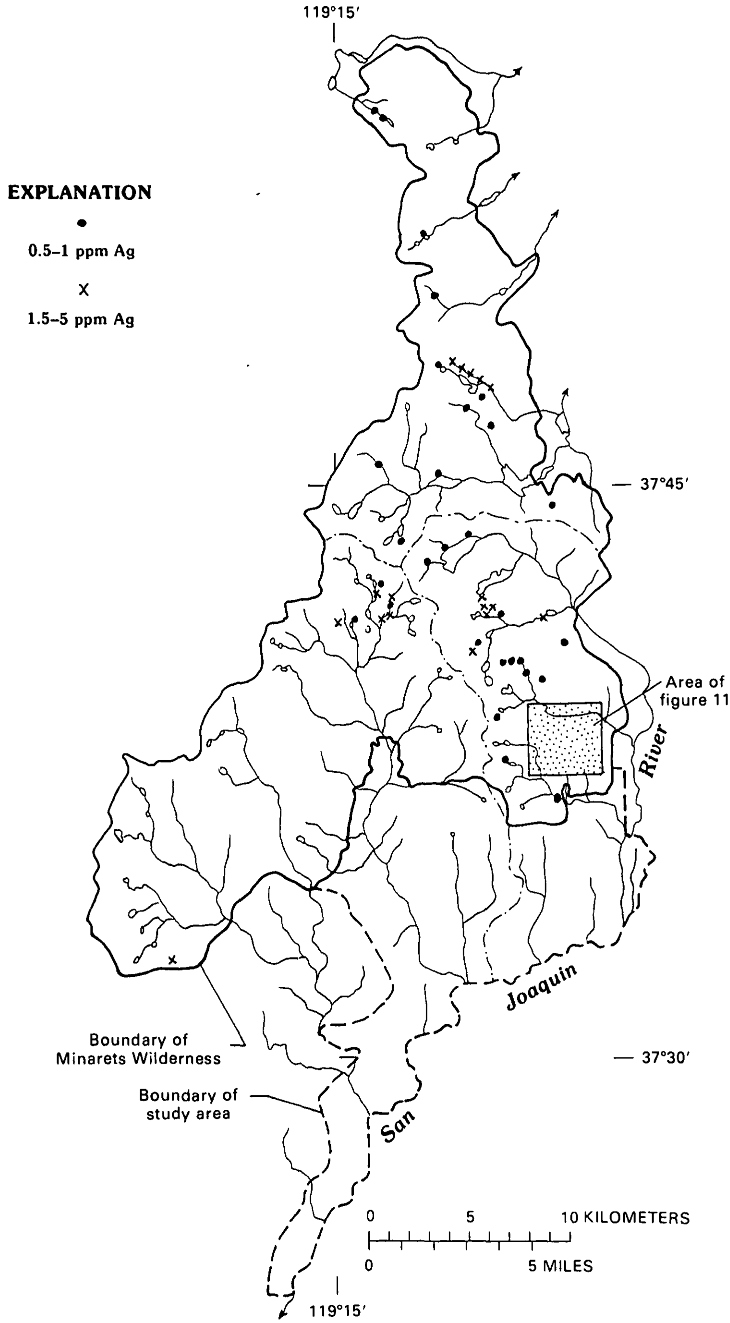


FIGURE 10.—Stream-sediment samples containing 0.5 parts per million (ppm) or more silver (Ag) in and near the Minarets study area.

(3) Mono Pass area, Walker Creek
(4) Upper Parker Creek basin
(5) Upper Alger Creek basin
(6) Nydiver Lakes-Cabin Lake-Minaret Creek belt
(7) Red Top Mountain area, west of Lost Dog Lake
(8) Upper North Fork San Joaquin River drainage, north of Twin Island Lakes
(9) Drainage below Lake Catherine
(10) Dike Creek drainage
(11) Upper Iron Creek drainage.

Evaluation of claims and prospects in these areas will be found in chapter D of this report.

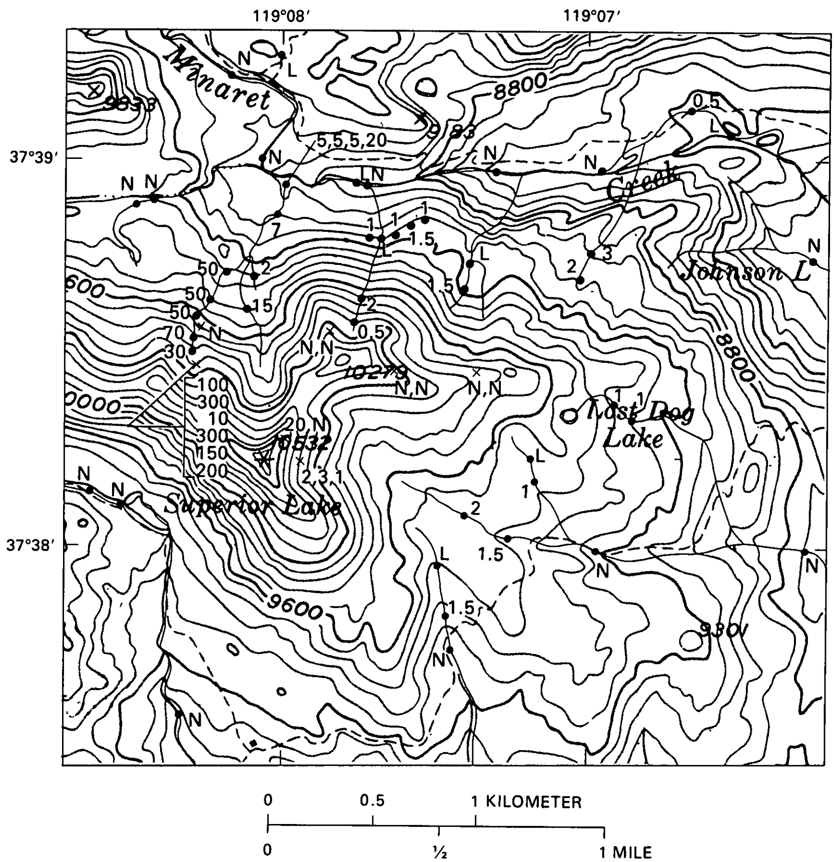


FIGURE 11.—Distribution of silver (in parts per million) in stream-sediment (dot) and rock (X) samples in the Red Top Mountain (*) area. N, not detected; L, detected but less than 0.5 ppm. See figure 10 for location of maps. Base from U.S. Geological Survey 15-minute quadrangle, Devils Postpile, 1953. Contour interval, 80 ft.

SILVER

Silver was described in the section above as being closely associated with anomalous concentrations of base metals and as having been detected in stream sediments in all of the areas listed except Kidney Lake, Dike Creek, and Iron Creek (fig. 10). In only one mineralized area, however, centered on Red Top Mountain west of Lost Dog Lake, was silver detected in stream sediments in excess of 5 ppm. The distribution of anomalous silver values in that area is shown on figure 11. Much of the mountain, particularly the south and southwest slopes, is sheathed with talus, which limits the places where stream-sediment samples could be obtained. The

TABLE 5.—*Partial analyses of stream-sediment samples from the Red Top Mountain area that are anomalous in silver or molybdenum*

[Number in parenthesis below element symbol is the lower limit of analytical determination; N, looked for but not detected; L, detected but below the limit of determination]

Field No.	Ag (0.5)	Mo (5)	Cu (5)	Pb (10)	Zn (5)	W (50)
3K001	0.5	5	30	70	120	N
3K004	N	30	20	50	90	L
3K009	5	L	50	100	60	N
3K033	N	30	20	30	25	N
3K034	N	30	20	50	70	N
3K115	5	10	70	30	100	N
3L003	N	30	15	30	60	N
3L013	N	20	20	50	50	N
3L025	N	20	50	50	70	N
3L026	N	30	15	50	30	N
3L027	N	30	30	50	60	N
3J010	N	50	20	30	90	L
4K083	7	10	70	100	70	N
4K084	2	10	30	70	35	N
4K085	15	N	70	100	40	N
4K086	70	N	50	200	65	N
4K087	50	N	50	200	80	N
4K088	5	N	7	100	50	N
4K089	5	N	70	100	55	N
4K090	2	N	70	70	30	N
4K091	.5	N	20	70	20	N
5K050	50	10	50	200	80	N
5K053	30	7	30	300	50	N
5K055	20	10	50	50	310	N
5K074	1	10	30	50	60	N
5K075	L	10	20	20	40	N
5K076	1	10	50	30	70	N
5K077	1.5	10	50	50	50	N
5K078	1	10	50	20	35	N
5K079	L	15	30	20	15	N
5K080	1.5	15	70	30	20	N
5K081	3	150	100	50	45	N
5K082	2	150	150	30	55	N
5K083	1	200	50	30	60	70
5K084	1	150	20	20	45	50
5K085	1	150	100	20	25	70
5K086	L	200	30	20	20	N
5K087	1.5	100	50	20	40	N
5K088	2	150	70	50	30	N
5K089	L	50	10	30	100	N
5K090	1.5	50	15	30	30	N

highest anomalous values are concentrated well up on the north slope of the mountain in a small drainage that enters Minaret Creek at about the 8,960-ft (2,730-m) contour (fig. 11; table 5).

The plutonic rock that makes up Red Top Mountain is predominantly granodiorite. It is strongly fractured or jointed, and on most of the mountain, the fractures and joints are stained with iron oxide, presumably derived from the oxidation of pyrite deposited with quartz and other minerals along the fractures. A series of aplite dikes with an average strike of N. 70° W. and near-vertical dip also cut the granodiorite.

Locally the granodiorite is strongly altered and sheared in zones that are irregular and discontinuous. Some shear zones are more continuous, however, and have a strike parallel to the aplite dikes. The shear zones contain considerable pyrite, now oxidized, and are various shades of red, brown, and yellow.

The sulfide minerals do not appear to be pervasive; where relatively fresh, as in the interior of joint blocks, the granodiorite shows no anomalous metal values (table 6).

The small drainage on the north slope of Red Top Mountain divides, about 820 ft (250 m) above its junction with Minaret Creek and each fork, heads in a cirque near the ridge crest. Stream-sediment samples from an area well up the west fork contain the highest anomalous silver values. At the lower end of the cirque on the west fork, a few scattered outcrops of locally sheared granodiorite project through the talus apron that fills most of the cirque. Some of these outcrops contain thin veins of black to brown material that has an oxidized, gossanlike appearance. Distribution of the vein material appears to be localized by the fracture pattern

TABLE 6.—*Partial analyses of rock and mineralized samples from the Red Top Mountain area*

[Number in parentheses below element symbol is the lower limit of analytical determination; N, looked for but not detected; L, detected but below the limit of determination]

Field No.	Ag (0.5)	As (200)	Au (0.05)	Bi (10)	Cu (5)	Mo (5)	Pb (10)	Sb (100)	Sn (10)	Zn (5)	Rock type
4E058	N	N	N	N	20	10	20	N	N	40	Granodiorite
Do.	N	N	—	N	15	N	20	N	N	—	Do.
4E059	N	N	N	N	20	10	20	N	N	45	Do.
Do.	N	N	—	N	15	N	20	N	N	—	Do.
4E057	N	N	N	N	20	50	20	N	N	15	Aplite dike
Do.	N	N	—	N	L	N	15	N	N	—	Do.
4K122	20	N	N	N	10	N	1,000	N	30	50	Sheared granodiorite.
Do.	N	N	N	20	10	N	30	N	200	—	Do.
5K054A	2	200	N	10	20	L	150	N	50	40	Altered granodiorite.
5K054B	3	200	N	30	15	N	100	N	50	15	Pyrite-rich zone
5K054C	1	200	N	20	5	N	50	N	50	10	Do.
5K051	N	N	N	L	200	N	20	N	N	6,500	Limonite filling in vug.
5K052A	100	700	1	1,000	200	10	300	L	N	150	Mineralized vein
5K052B	300	2,000	N	200	200	L	10,000	500	150	150	Do.
5K052C	10	2,000	0.8	100	50	15	2,000	100	20	160	Do.
5K052D	300	700	N	500	200	N	1,000	500	300	90	Do.
5K052E	150	2,000	N	200	200	N	3,000	L	30	350	Do.
5K052F	200	1,500	0.1	500	300	N	7,000	100	20	270	Do.

in the granodiorite, and most of it apparently occurs as thin coatings on the surfaces of loosened blocks of granodiorite. Vuggy veings, as thick as half an inch (1 cm), occur in sheared granodiorite. Analyses of this dark vein material indicate the presence of highly anomalous silver as well as other metallic elements (field Nos. 5K052A through 5K052F, table 6).

No obvious prospect workings were noted in this cirque, and no identifiable sulfide minerals were seen except for scattered unoxidized pyrite grains in some of the sheared granodiorite. The mineralized veins appear to be too narrow and too sparsely distributed to constitute a viable deposit. A full evaluation would require considerably more analytical data and fieldwork than were available during the present reconnaissance.

MOLYBDENUM

Stream-sediment samples containing anomalous amounts of molybdenum, 20 ppm or more (table 5), occur chiefly in an area south of Minaret Creek on the east slope of a peak with twin prominences of 10,532- and 10,279-ft (3,210 and 3,133 m) elevation (figs. 12 and 13). This is the peak referred to as Red Top Mountain by Erwin (1934, p. 71 and 78), who described an occurrence of molybdenum on the east slope of this peak in small quartz veinlets cutting granitic bedrock, referred to in this report as the granodiorite of Lost Dog Lake. The quartz veinlets are described as wider than 5 cm and containing molybdenite scattered throughout the quartz and in cavities. The location of this specific locality, referred to as the Dream Lake Group of claims and shown as an X on Erwin's map, is uncertain, although numerous prospects on the east slope of the peak are described in chapter D of this report.

The sediment samples with the highest anomalous molybdenum in this area also contain anomalous copper and detectable amounts of silver (fig. 11; table 5), although the highest values for silver are found on the north side of the peak, where molybdenum values are below the anomalous threshold. The intensity and geographic extent of molybdenum mineralization is unknown, although a considerable area of at least minor mineralization is indicated both by the anomalous values in the stream sediments and by the abundance of scattered prospect workings in the general area.

Anomalous molybdenum, mostly at or just above the threshold value, occurs in a few samples scattered through the southern and in the far northern parts of the study area (fig. 12), but only southwest of Iron Mountain, below the Minarets magnetite deposit, is there any concentration of anomalous samples (four samples, each with 20 ppm Mo). The highest of the anomalous values

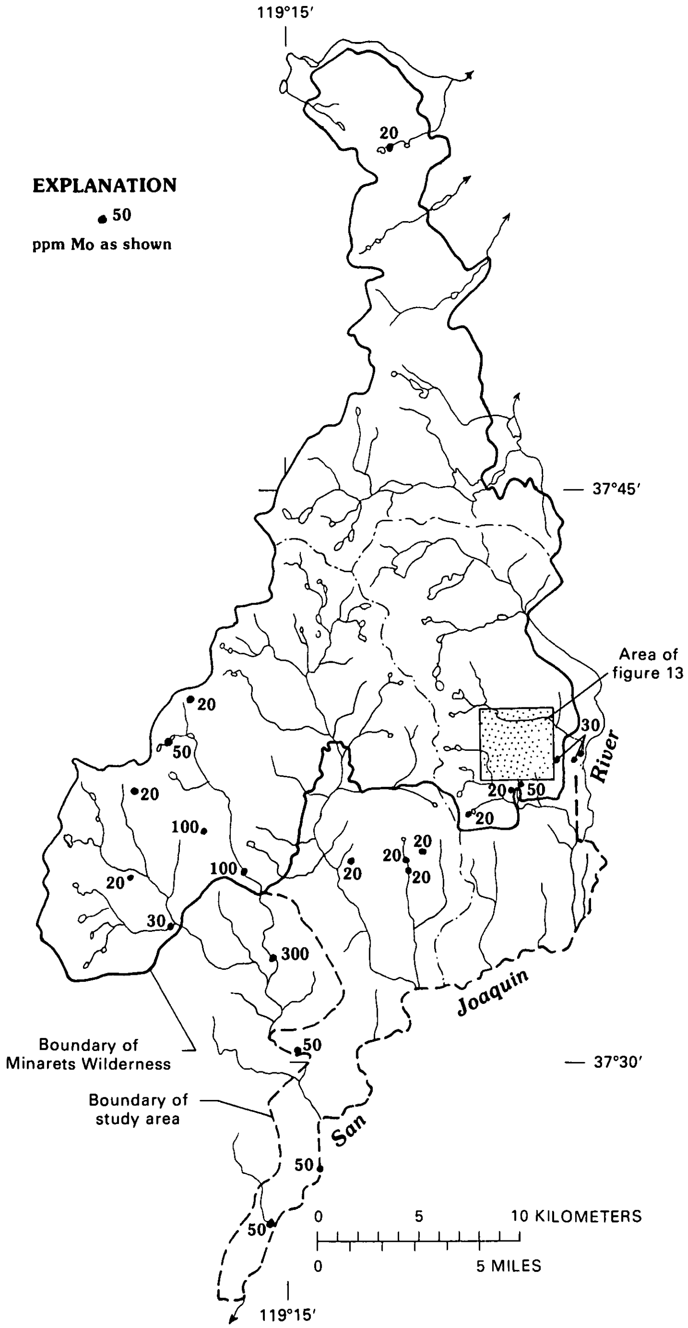


FIGURE 12.—Stream-sediment samples containing 20 parts per million (ppm) or more molybdenum (Mo) in and near the Minarets study area.

outside of the Red Top Mountain area, those in the drainage basin of the East Fork Granite Creek, are not reinforced by data from adjacent samples, and so their significance is unknown. Local contamination by human activities is suspected.

TUNGSTEN AND TIN

Of all the stream-sediment samples analyzed in this study, only nine yielded tungsten in amounts of 50 ppm or more, the lower limit of detection by spectrographic methods. Five of these, including all the highest amounts found, were collected on Granite Creek and the San Joaquin River downstream from the Strawberry tungsten deposit (fig. 14). Thus, these otherwise anomalous amounts are

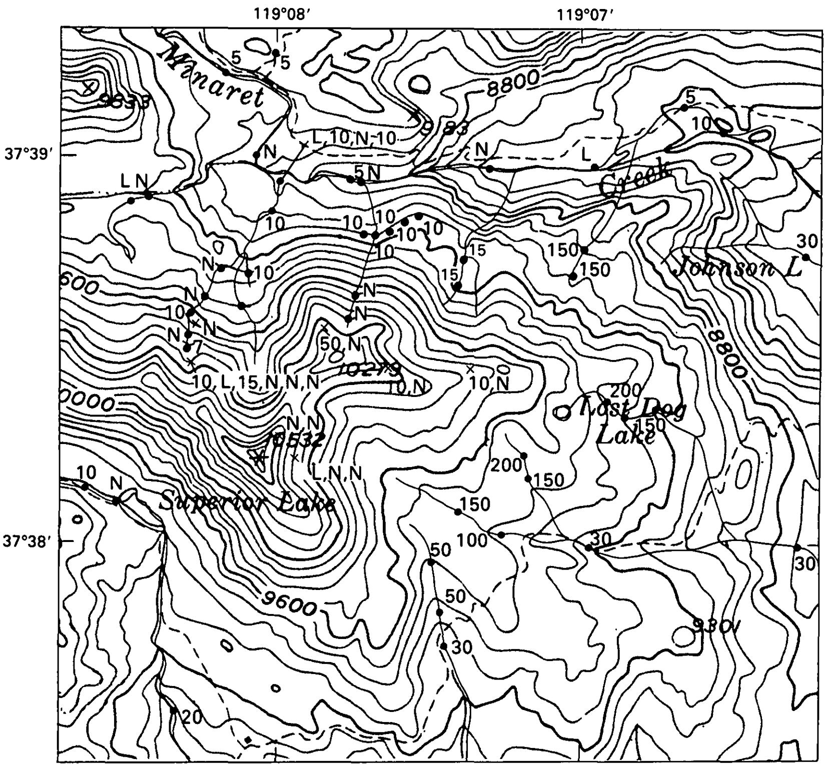


FIGURE 13.—Distribution of molybdenum (in parts per million) in stream-sediment (dot) and rock (X) samples in the Red Top Mountain (*) area. N, not detected; L, detected but less than 5 ppm. Base from U.S. Geological Survey 15-minute quadrangle, Devils Postpile, 1953. Contour interval 80 feet.

readily explained by the presence of that deposit.

Four additional stream-sediment samples contained tungsten, but only slightly more than the lower limit of detection. One is from the upper Cargyle Creek drainage downslope from the Minarets magnetite deposit, and the three others are from the area west of Lost Dog Lake, where they are associated with anomalous molybdenum.

The same five tungsten-bearing stream-sediment samples collected downsteam from the Strawberry tungsten deposit also are the only ones that contained 10 ppm or more tin, the lower detection limit for that metal. These otherwise anomalous amounts of tin can be explained by the presence of small amounts of tin in the tungsten-bearing tactite of the Strawberry deposit (table 7), and do not indicate tin resources in the study area. Tin was also detected in some mineralized rock samples from the Red Top Mountain area (table 6).

GOLD

The geochemical survey yielded only minor traces of gold, and only 12 stream-sediment samples contained 0.05 ppm or more gold, the lower limit of detection by atomic-absorption methods. The highest value was 3 ppm for two samples; all the others had less than 1 ppm (fig. 15). The stream sediments were not collected by optimum methods for detecting gold (such as panned concentrates from pockets in bedrock), and the particulate nature of placer gold makes it difficult for the small samples analyzed to be representative. Nevertheless, the possibility of economic concentrations of gold in the study area does not appear promising.

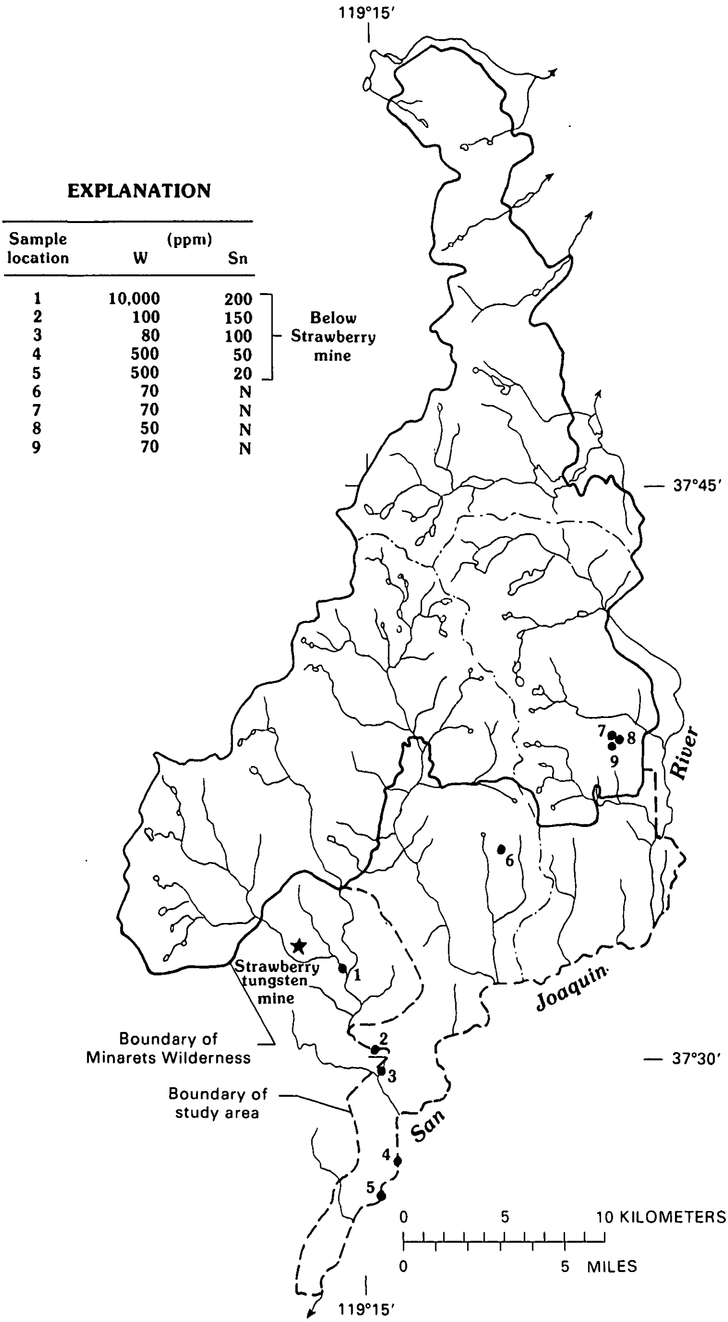
CHROMIUM AND NICKEL

Steam-sediment samples from points throughout the study area generally show low values in chromium and nickel; maximums are 600 ppm for chromium and 300 ppm for nickel (mean of 21 ppm Cr and 13 ppm Ni). For comparison, in the Salmon-Trinity Alps Primitive Area in northern California, where numerous sediment

TABLE 7.—*Partial analyses of mineralized tactite from the Strawberry tungsten deposit*[1]

Field No.	W (ppm)	Sn (ppm)
GC-156b	70,000	30
GC-156a	20,000	30
GC-182	50,000	200

[1]Samples collected by W. J. Nokleberg; semiquantitative spectrographic analyses by H. G. Neiman.



EXPLANATION

Sample location	W (ppm)	Sn (ppm)	
1	10,000	200	Below Strawberry mine
2	100	150	Below Strawberry mine
3	80	100	Below Strawberry mine
4	500	50	Below Strawberry mine
5	500	20	Below Strawberry mine
6	70	N	
7	70	N	
8	50	N	
9	70	N	

FIGURE 14.—Stream-sediment samples containing 50 parts per million (ppm) or more tungsten (W) and 10 ppm or more tin (Sn) in and near the Minarets study area.

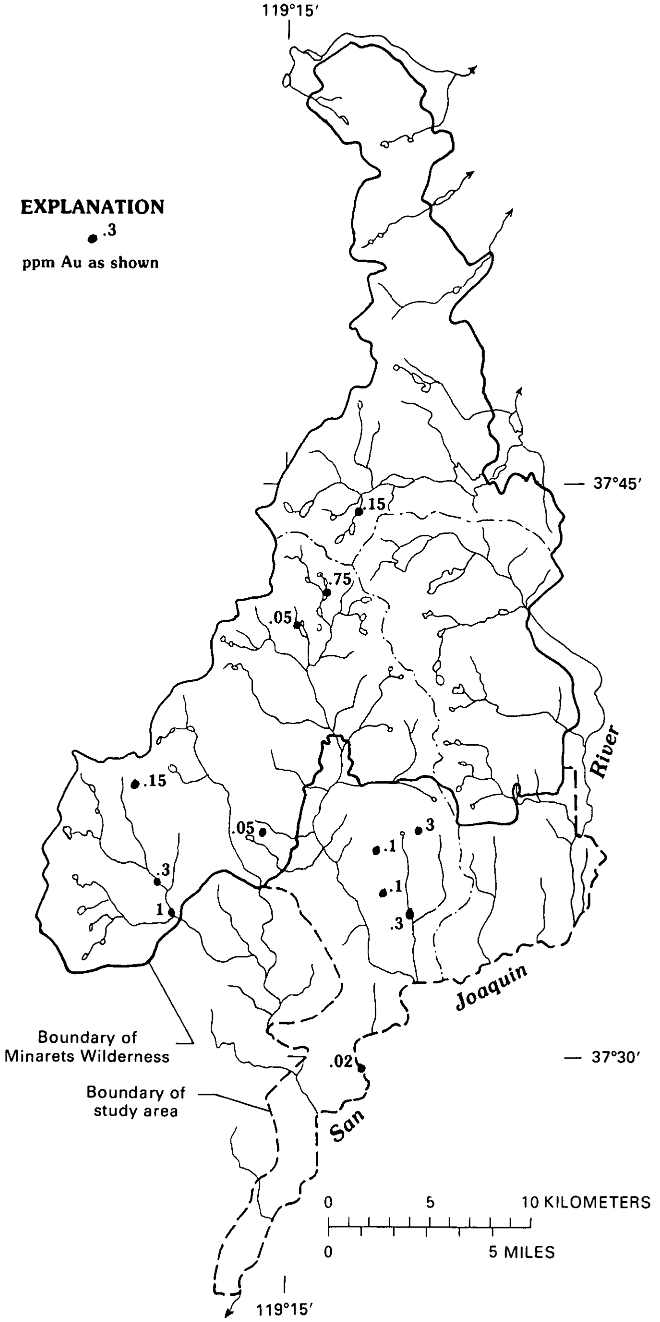


FIGURE 15.—Stream-sediment samples containing 0.05 parts per million (ppm) or more gold (Au) in and near the Minarets study area.

samples contain more than 1,000 ppm of both chromium and nickel, no economic deposits of these elements are known (Hotz and others, 1972).

Nevertheless, values of 70 ppm or more chromium or 30 ppm or more nickel are statistically anomalous when considered as part of the overall population of stream-sediment samples in the Minarets study area. Inspection of figures 16 and 17, on which all such anomalous values have been plotted, indicates clearly that almost without exception, all are closely associated with exposures of late Pliocene and Pleistocene basalt. Such basalt uniformly contains chromium and nickel in significantly greater abundance than the silicic metavolcanic and granitic rock that underlies most of the study area (table 8). These differences in bedrock background values account for the somewhat higher, but not economically significant, values of chromium and nickel in sediment from streams draining the areas where basalt is exposed. This also is an excellent example of a bimodal distribution of analytical values reflecting two distinct populations (fig. 6)—in this case, two different background populations rather than mineralization superimposed on a single background population.

The highest values for cobalt, though not distinctly anomalous, are also associated with the basalt.

BORON

Boron is a trace element that has been used as an indicator of high-temperature ore deposits, such as those in pegmatites and polymetallic veins and lodes, where it occurs chiefly in the mineral tourmaline or, less commonly, in axinite (Boyle, 1971). Of the stream-sediment samples considered anomalous in boron (70 ppm or greater) (fig. 18), those in the northern part of the study area are from drainage basins containing pegmatitic quartz veins and pods. The quartz veins also contain scattered concentrations of sulfide minerals, and some sediment samples are anomalous in base metals and silver (Crest Creek, Alger Creek, Parker Creek). The boron is assumed to be present in tourmaline, although none has been specifically identified.

TABLE 8.—*Comparison of average chromium and nickel content for selected rock types*

Rock type (number of samples)	Arithmetic mean (ppm)	
	Cr	Ni
Granitic rocks, study area (29)	10	<10
Granitic rocks, Sierra Nevada (545)[1]	30	10
Metavolcanic rocks, study area (80)	26	12
Cenozoic volcanic rocks, study area (10)	222	252

[1]Dodge (1972).

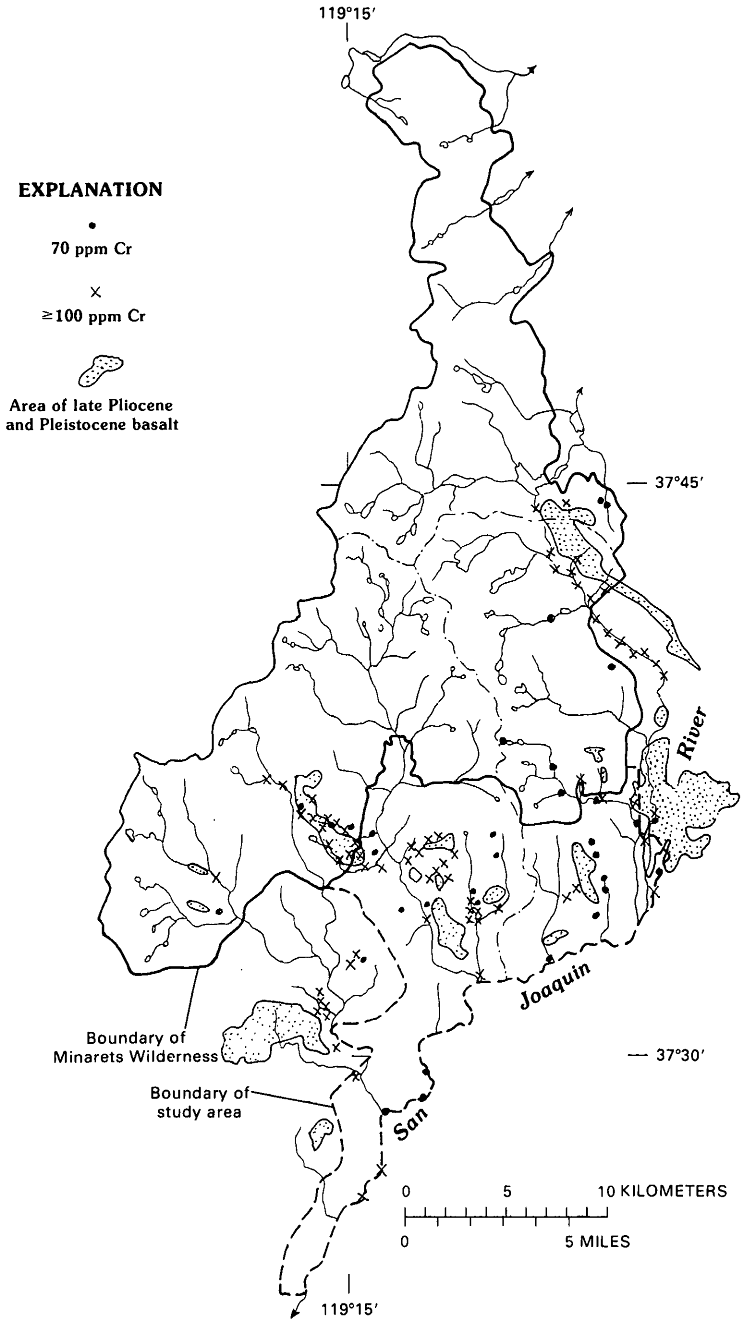


FIGURE 16.—Stream-sediment samples containing 70 parts per million (ppm) or more chromium (Cr) in and near the Minarets study area.

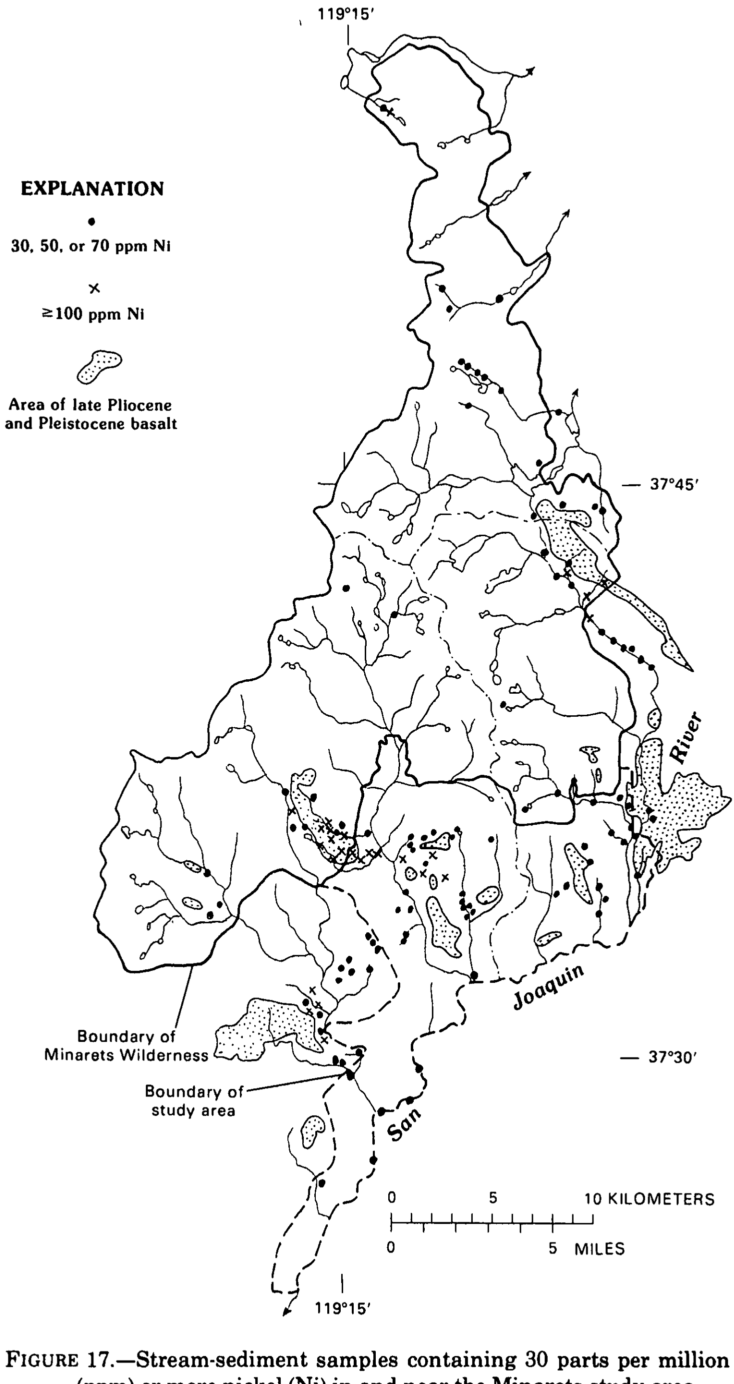


FIGURE 17.—Stream-sediment samples containing 30 parts per million (ppm) or more nickel (Ni) in and near the Minarets study area.

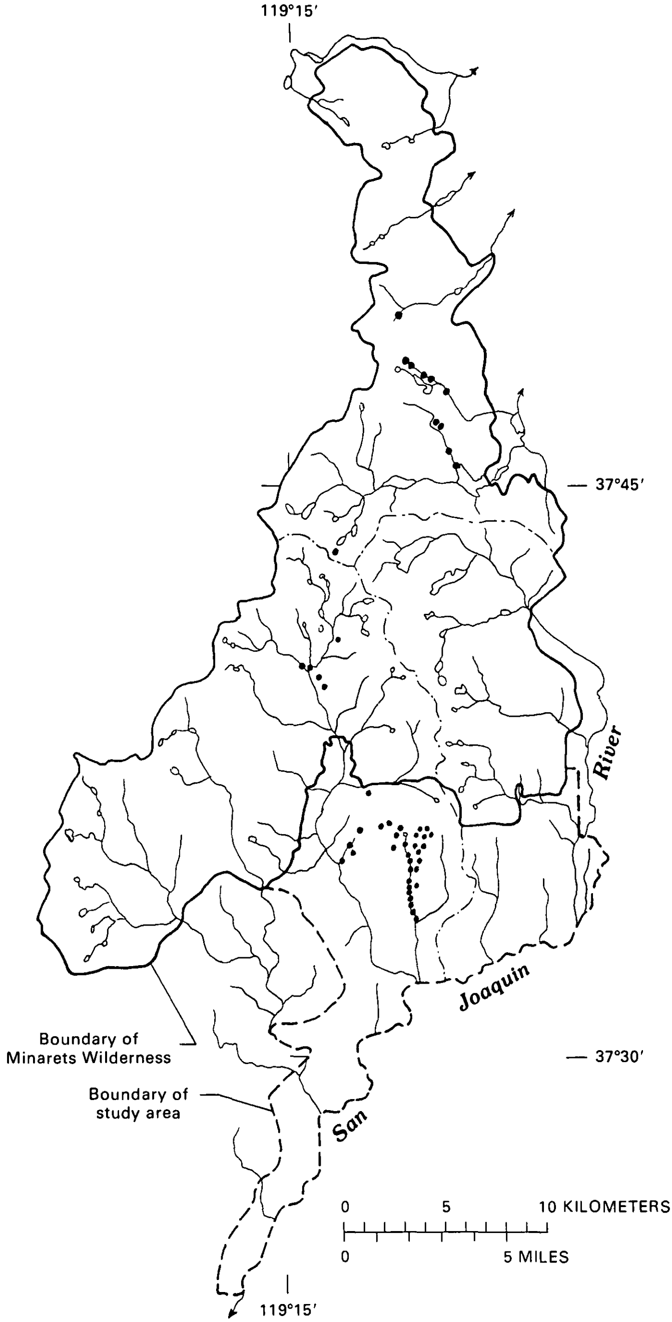


FIGURE 18.—Stream-sediment samples containing 70 parts per million (ppm) or more boron (B) in and near the Minarets study area.

Near Stevenson Meadow in the North Fork San Joaquin River drainage, several sediment samples with anomalous boron appear to be associated with an elongate zone of andalusite muscovite schist, which locally contains epidote, garnet, pyrophyllite, and sparse metallic sulfides, chiefly bornite. Thin veinlets and pods of dark-blue lazulite also are present, and some have been worked for specimen material. Thus, in this area the boron does not appear to be associated with significant metallic mineralization.

The major boron anomaly in the study area is in the upper drainage of the West Fork of Cargyle Creek, southwest of Iron Mountain, where some sediment samples contain as much as 200 ppm boron. Examination of the analyzed samples reveals small grains of tourmaline, sparse but in an amount that probably is sufficient to account for the anomalous boron. The drainage area yielding the anomalous samples is underlain by four different geologic units, including both felsic and mafic intrusive rocks and metavolcanic rocks. Because very fine grained tourmaline has been identified in thin sections of several rock types, it appears to have been introduced over a broad area rather than to be a localized component, as in the pegmatites or quartz veins. The only significant metallic mineral recognized in the area is that of the Minarets magnetite deposit, a type of deposit generally low in boron (Landergren, 1948; Radtke, 1965). Base metals and silver, which are associated with anomalous boron in the Alger Creek drainage, are not anomalous in the Cargyle Creek sediment samples, and thus the tourmaline cannot readily be correlated with either the bedrock geology or known metallic mineralization.

VANADIUM

Vanadium in amounts more than two standard deviations greater than the geometric mean (200 ppm or greater) occurs in stream-sediment samples in scattered localities in the study area. Concentrations of such samples only occur, however, in the Cargyle Creek drainage and along the San Joaquin River below the mouth of Cargyle Creek (fig. 19). Vanadium is commonly concentrated in magnetite deposits, particularly in the titaniferous varieties (Fischer, 1975). On the basis of a single spectrographic analysis of magnetite from the Minarets magnetite deposit, the magnetite does not appear to be especially titaniferous, although the sample does contain 1,000 ppm vanadium (table 9), and the anomalous vanadium in the stream-sediment samples probably reflects the magnetite mineralization in the area. From the viewpoint of the geochemical study, vanadium might be considered a

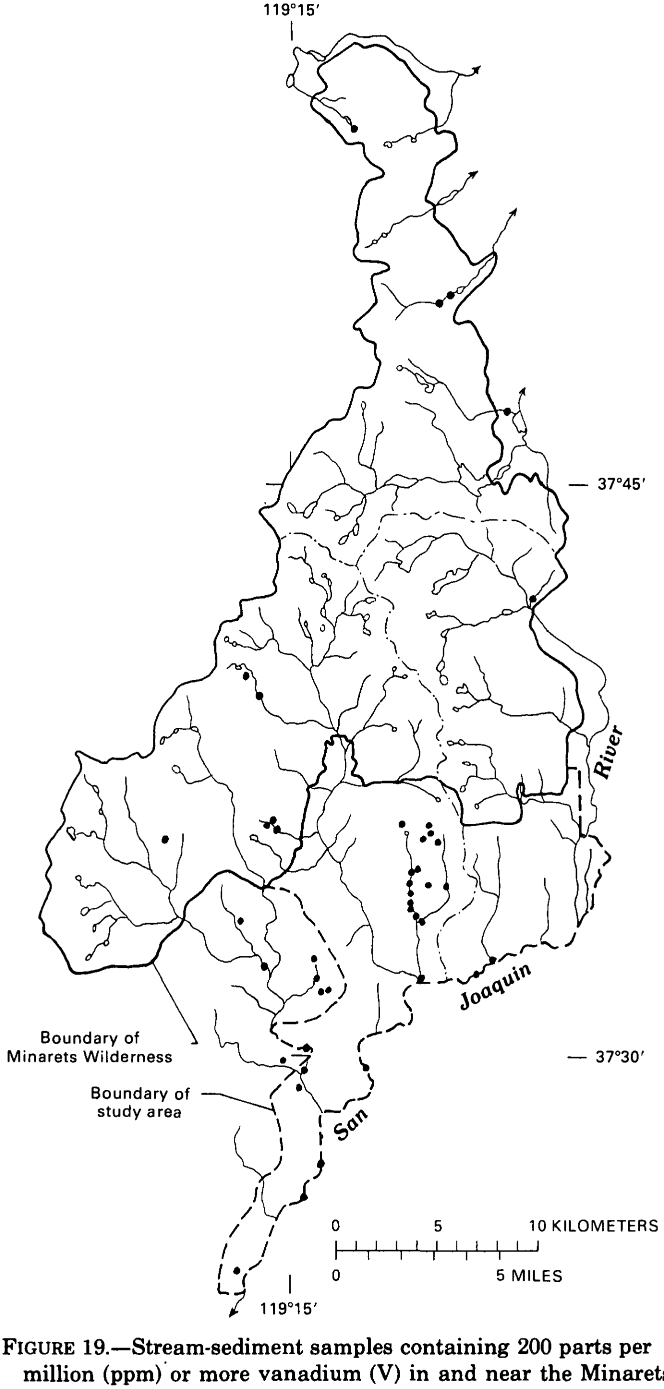


FIGURE 19.—Stream-sediment samples containing 200 parts per million (ppm) or more vanadium (V) in and near the Minarets study area.

TABLE 9.—*Analysis of massive magnetite from the Minarets magnetite prospect*

[Chemical analyses reported as oxides by H. C. Whitehead; spectrographic analyses for minor elements by R. E. Mays]

Oxide percent	
Fe_2O_3	70.7
FeO	26.5
H_2O^-	.0
Element percent	
Cu	0.007
Si	1
Mn	.085
Co	.0060
Ni	.20
Cr	<.0004
V	.10
Al	.11
Ti	.015
Zr	.006
Mg	.18
Ca	.24
Ba	.0006

tracer for magnetite; indeed, it is the only tracer element that was recognized during the present survey, unless the tourmaline causing the boron anomaly in the same drainage is also related to the mineralizing event that produced the magnetite deposit. Iron itself is not present in anomalous amounts in the stream sediment downstream from the Minarets iron deposit. The massive magnetite ore is extremely resistant to both chemical weathering and mechanical disintegration, and although it occurs as pebbles in the stream, it contributes relatively little to the fine sediment used for analysis, in comparison with the iron derived from weathering and disintegration of the more granular country rocks.

RADIOACTIVE ELEMENTS

The stream-sediment samples collected during the geochemical survey were not analyzed for radioactivity. Fifty rock samples were instrumentally analyzed, however, and none had more than 70 ppm reported as equivalent uranium. In addition, all samples collected from mineralized areas by U.S. Bureau of Mines personnel were routinely scanned for radioactivity.

SIGNIFICANCE OF THE GEOCHEMICAL SURVEY

The geochemical survey did not reveal any mineralized areas of significant size or concentration that were previously unknown, inasmuch as all areas in which the stream sediments contain anomalous values for various metals also contain numerous claims and prospect workings. Perhaps this is not surprising in consideration of the extensive rock exposures that are present and the intensity of past prospecting activity.

The geochemical data are of considerable value, however, in providing information on the distribution of elements that are not visually identifiable even in known mineralized areas. Copper, lead, and zinc, for example, generally occur in such readily recognized minerals as chalcopyrite, galena, and sphalerite, whereas silver can generally be detected only by analytical means. Thus the data indicate that silver is present to some degree in virtually all the mineralized areas containing copper, lead, and zinc, and also is present in an obviously altered and mineralized zone on the north side of Red Top Mountain in which pyrite is the only sulfide mineral recognized in outcrop.

It also was reassuring to find anomalous concentrations of molybdenum in stream sediments in an area of known but diffuse molybdenite mineralization, thus adding validity to the efficacy of the geochemical method for the detection of this element.

Geophysical Studies of the Minarets Wilderness and Adjacent Areas, Madera and Mono Counties, California

By HOWARD W. OLIVER, U.S. GEOLOGICAL SURVEY

MINERAL RESOURCES OF THE MINARETS WILDERNESS AND ADJACENT AREAS, MADERA AND MONO COUNTIES, CALIFORNIA

GEOLOGICAL SURVEY BULLETIN 1516-B

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GEOPHYSICAL STUDIES OF THE MINARETS WILDERNESS AND ADJACENT AREAS, MADERA AND MONO COUNTIES, CALIFORNIA

By HOWARD W. OLIVER, U.S. GEOLOGICAL SURVEY

SUMMARY

An aeromagnetic survey of the study area was flown along east-west lines spaced approximately 1 mi (1½ km) apart at an elevation of 13,500 ft (4,000 m). Most of the magnetic anomalies revealed by the survey are associated with the topography or are consistent with the magnetic properties of the rocks exposed at the surface. However, two unusual anomalies of 400–500γ (gammas) occur near Iron Mountain and Mount Gibbs. Ground magnetic data were obtained in those areas. The ground data and calculations show that the Iron Mountain aeromagnetic anomaly reflects the coalescence of an 80,000γ ground-level anomaly over the Minarets iron deposit and a much weaker but wider anomaly associated with metavolcanic rocks that are more mafic in this area than average for the Ritter Range pendant. The source rocks of the Mount Gibbs anomaly are not exposed. Ground data south of that anomaly reveal a northwest-trending elongate anomaly of 1,500γ over prospects at Mono Pass that may indicate a continuation of the mineralized zone.

INTRODUCTION

Past experience has shown that aeromagnetic surveying with 1-mi (1½ km) spacing is a useful reconnaissance method for locating iron deposits and serpentinite bodies in the Sierra Nevada (Henderson and others, 1966; U.S. Geological Survey, 1969, 1976; Cady, 1975). Although serpentinite is not of economic importance in itself except for its fibrous form (asbestos), its direct association with chromite and its indirect association with primary gold and silver along the Mother Lode fault zone make it a worthwhile exploration target (Ferguson and Gannett, 1932, p. 75–76; Peterson and others, 1968; Yeend, 1974; Duffield and Sharp, 1975, p. 26). More detailed airborne and ground magnetic surveys have also been useful in locating and evaluating deposits of copper, lead, zinc, and tungsten by their association with such magnetic minerals as magnetite or pyrrhotite (Horvath and Davidson, 1958).

Aeromagnetic surveys of the Emigrant Basin and High Sierra Wilderness areas, to the northwest and southeast of the present study area, respectively, have shown that some of the granitic plutons that make up the Sierra Nevada batholith are associated with magnetic anomalies of several hundred gammas at flight elevations of a thousand meters or so above the ground surface (Oliver, 1970, 1972). Laboratory studies of samples have demonstrated that the anomalies reflect induced magnetization of finely disseminated grains of magnetite, which commonly constitute about 1 percent of the rocks. Larger anomalies (as high as 600γ) occur over some of the metavolcanic rocks, whereas other metavolcanic rocks and most of the metasedimentary rocks are relatively nonmagnetic.

In this chapter, regional gravity data are summarized, a reconnaissance aeromagnetic survey is discussed (pl. 3), and ground magnetometer and sampling studies are interpreted. These detailed ground studies are at the Minarets magnetite deposit, the Mono Pass prospects, and the Mount Gibbs area.

Acknowledgments.—R. F. Sikora assisted with the ground magnetometer measurements at Mount Gibbs and Mono Pass and made the density and magnetic property measurements on samples from those areas. Samples of the Minarets iron deposit and surrounding country rocks were collected by U.S. Bureau of Mines personnel, and the magnetic properties determined by D. E. Champion and K. D. Holden.

REGIONAL GRAVITY STUDIES

Gravity measurements with a station spacing of 2 to 3 mi (3–5 km) were made in the Minarets Wilderness and vicinity, primarily from 1968 to 1971, as part of a more extensive structural and geodetic study of the Sierra Nevada (Oliver, 1969). A Bouguer gravity anomaly map covering the Sierra Nevada between lat 37° and 38° N. at a scale of 1:250,000 was released (Oliver and Robbins, 1973), and a complete documentation of the data was published later by Robbins, Oliver, and Huber (1975). These data were reexamined for anomalies that might bear on the mineral-resource evaluation, although the data within the study area are too general to be of significant value in this regard.

A recent structural interpretation of somewhat more detailed gravity data in the northern part of the present study area (Oliver, 1977, fig. 5) suggests that the metavolcanic and metasedimentary rocks that form the northward extension of the Ritter Range pendant west of Grant Lake (pl. 1) do not extend to great depth, perhaps only about 2 mi (3 km). The metasedimentary rocks appear to have a bottom surface that parallels the arching surface topography across the Sierra Nevada crest in this area. Although these gravity data have important structural implications with respect to the configuration of the batholith and its wallrocks, they do not provide any new information of economic significance.

AEROMAGNETIC SURVEY

A total-intensity aeromagnetic survey using a proton-precession magnetometer was flown and compiled in 1973 along a series of west-east lines spaced approximately 1 mi (1.6 km) apart. The aeromagnetic map (pl. 3) shows the residual magnetic intensity calculated by subtracting the International Gravity Reference Field (IGRF) from the total intensity. The locations of the flightlines, shown on the map by a series of dots (pl. 3), were determined by continuous-strip photography. Fiducial points are marked on the original analog records about every 2 mi (3 km) and correspond to known locations marked on the photographs. A radar altimeter was in operation during the survey but did not record unless the plane was within about 1,700 ft (500 m) of the ground surface. Because the survey was flown at a constant altitude of about 13,500 ft (4,100 m), the altimeter was not recording when crossing topography lower than about 11,800 ft (3,600 m) in elevation. However, the few altitude records that were obtained when the plane was crossing peaks higher than 11,800 ft (3,600 m) were helpful for checking locations relative to the peaks.

RELATIONS BETWEEN MAGNETIC ANOMALIES, TOPOGRAPHY, AND GEOLOGY

The topographic relief over the study area is extreme; the ground elevation ranges from about 3,300 ft (1,000 m) in the southern part to more than 13,000 ft (4,000 m) at Mount Ritter. Most rocks in the area contain a fraction of a percent magnetite and are slightly magnetic, having magnetizations in the range from 20×10^{-4} to 50×10^{-4} emu/cm^3 (see table 10). Prism-shaped mountains of such material in California normally have aeromagnetic highs over their southwest flanks and smaller associated magnetic lows to the northeast (Vacquier and others, 1951, p. 114-127). Similarly, valleys cut into such magnetized material will have a magnetic low over the southwest part of the valley and a smaller high to the northeast. Topographic ridges have varying effects depending on their orientations relative to magnetic north. For example, a 3,000 ft (900 m) north-south topographic ridge 1,600 ft (500 m) below the aircraft with a magnetization of 10×10^{-4} emu/cm^3 in the direction of the Earth's field will cause an anomaly of about 150γ nearly over the ridge and a broad associated low of about -30γ centered about 3 mi (5 km) to the east.

The strongest magnetic highs that are clearly caused by topography are located along the west boundary of the study area between Sing Peak (anomaly D) and Mount Lyell (anomaly L). The boundary follows a continuous topographic ridge between these two peaks that ranges from 10,000 to 13,000 ft (3,000–4,000 m) in elevation and rises 2,300 to 5,600 ft (700–1,700 m) above the surrounding terrain. Other magnetic highs associated with topographic highs are anomalies B, E, and F (pl. 3). Anomaly U, about 1 mi (1½ km) east of Mount Gibbs, is partly associated with topography, in that the flightline to the north of the anomaly shows a maximum value of nearly 200γ directly over the Sierran crest. However, the maximum magnetic value along the flightlines to the south is displaced about 1 mi (1½ km) to the east of the crest. Thus, anomaly U is complex and will be discussed in greater detail in a later section.

Magnetic lows related to topography include anomaly A over the canyon of the San Joaquin River, the magnetic trough between anomalies C and G that follows the 2,500-ft (750 m)-deep valley cut by the North Fork San Joaquin River, another magnetic trough between anomalies J^1 and J^2 over the valley of the Middle Fork San Joaquin River north of Devils Postpile National Monument, and anomaly O north of Mount Lyell. Anomaly O of -211γ, in addition to occurring over a topographic low, lies about 2 mi (3 km) north-northwest of the magnetic high "H547" (anomaly L) on the southwest flank of Mount Lyell and is partially associated with it.

Magnetic lows also occur over nonmagnetic to weakly magnetic rocks. The 8-mi (13 km)-long magnetic trough that strikes northwest and culminates in anomalies S and T correlates closely with the outcrop pattern of Permian(?) metasedimentary rocks. According to Kistler (1966b), these rocks are virtually devoid of magnetite and are therefore nonmagnetic. Anomaly I with a low value of -289γ is centered over a topographic low, but the magnetic trough extending to the northwest is situated over the quartz monzonite of Shellenbarger Lake, which is a leucocratic rock containing albite phenocrysts in a micrographic groundmass (see Chapter A, this volume). Although the magnetic properties of this rock unit are not known, this excellent correlation suggests that the unit is essentially nonmagnetic (J_T less than 5×10^{-4} emu/cm^3).

The only magnetic low that does not occur over a topographic low or over rocks known to be nonmagnetic is anomaly V, situated about 2 mi (3 km) N. 15° E. of the Mount Gibbs magnetic high (anomaly U). Anomaly V, with a minimum value of −323γ, occurs over the east edge of Dana Plateau, where the ground elevation is about 11,000 ft (3,400 m); to the east, the total magnetic intensity increases several hundred gammas in spite of a decrease in ground elevation of about 3,300 ft (1,000 m). Anomaly V occurs over a part of the Triassic granitic rocks for which sample data on magnetic properties are not available. However, judging from the aeromagnetic data over Dana Plateau, these rocks are only weakly magnetic. The direction of the position of anomaly V relative to anomaly U is nearly magnetic north; this areal relation suggests that anomalies U and V are due to the same magnetic mass, and so the position of anomaly V may be related to the north boundary of the mass. There is also a possibility that the granitic rocks under this anomaly are reversely polarized or that they have lost their magnetism by mineralogic alteration.

Pronounced magnetic highs occur over several areas of metavolcanic rocks. The sharpest such anomaly is anomaly H, which is situated about 4 mi (6 km) west of Devils Postpile National Monument and near Iron Mountain and has a maximum value of 277γ. Others include "H37" (anomaly K) near Minaret Lake and a northwest-trending lineament of several magnetic highs, "H138" (anomaly Q) and "H154" (anomaly R), near the contact between the metavolcanic rocks and the Cretaceous granitic rocks 2 to 2½ mi (3-4 km) north of Waugh Lake. The metavolcanic rocks in these particular areas are more mafic than in the other areas of exposed metavolcanic rocks and are generally classified as distinctive geologic units, as shown on the more detailed geologic quadrangle maps of Devils Postpile (Huber and Rinehart, 1965a) and Mono Craters (Kistler, 1966a).

The granitic rocks appear to be quite variable magnetically. The most distinctive highs occur over the Cretaceous granitic rocks near Thousand Island Lake (anomaly M, "H130", pl. 3) and near Donahue Pass (anomaly P, "H100", pl. 3). These particular granitic rocks are of the granodiorite of Kuna Crest (Kistler, 1966a) and are rather mafic, containing approximately 20 percent dark minerals. Additional magnetic data over this unit in Yosemite National Park (U.S. Geological Survey, 1974) indicate that these rocks are substantially magnetic because they underlie magnetic anomalies of 200-300γ at distances of 2,300 to 3,300 ft (700-1,000 m) below the level of measurement (see fig. 26).

Most of the magnetic anomalies within the study area thus are related either to topography or to common types of rocks known to be magnetic (in the case of highs) or nonmagnetic (in the case of lows). Because of the possible economic significance of the Iron Mountain and Mount Gibbs anomalies (H and U, respectively), they were studied in detail, and the results are described in the following sections. Anomaly V north of Mount Gibbs is also of possible economic concern if this magnetic low represents mineralogic alteration; ground studies in this inaccessible area are beyond the scope of the present geophysical study.

IRON MOUNTAIN MAGNETIC HIGH

Aeromagnetic anomaly H near Iron Mountain, "H277" (pl. 3), is situated over areas of magnetite mineralization known collectively as the Minarets magnetite or iron deposit (fig. 20). The description and evaluation of this deposit are included in Chapter D of this volume, and so the discussion here will be limited to the magnetic properties of the deposit and their aeromagnetic signature. A fundamental question is whether the aeromagnetic anomaly is caused by the iron deposit, the metavolanic rocks, or both. Moreover, if the iron deposit contributes significantly to the anomaly, could any other magnetic highs within the study area, such as the one near Mount Gibbs (anomaly U), reflect undiscovered iron deposits?

One of the flight paths that crossed directly over the largest of the Minarets iron deposits (line K-K′, fig. 20) provides data on the magnetic effect as seen from 3,000 to 3,300 ft (900–1,000 m) above the variable ground surface. A tracing of the original record along line *K-K′* (pl. 3) is shown in figure 21, together with a qualitative geologic cross section interpreted partly from the data. The position of the maximum magnetic intensity is about 1,000 ft (300 m) east of the iron deposit and about 2,000 ft (600 m) west of Iron Mountain itself. (Iron Mountain was named for its proximity to the iron deposit rather than being rich in iron in itself.)

At the largest iron deposit (fig. 22), seven samples were taken and magnetic properties measured on them (see tables 10 and 11), and 10 ground magnetometer profiles (*A* to *J*) were provided for this study by a private exploration company. The four profiles having a magnetic effect greater than 50,000γ are illustrated in figure 23, along with their interpreted sections. Profile *E-E′* across the south end of the deposit has the highest measured vertical magnetic anomaly of about 80,000γ, but measurements along *D-D′*, a short distance to the north, went off scale and are greater. The magnetic amplitude along profile *B-B′* (not illustrated) is about 10,000γ, and the anomaly broadens and drops off in amplitude to about 2,000γ along *A-A′*. South of the exposed deposit, magnetometer profiles *G*

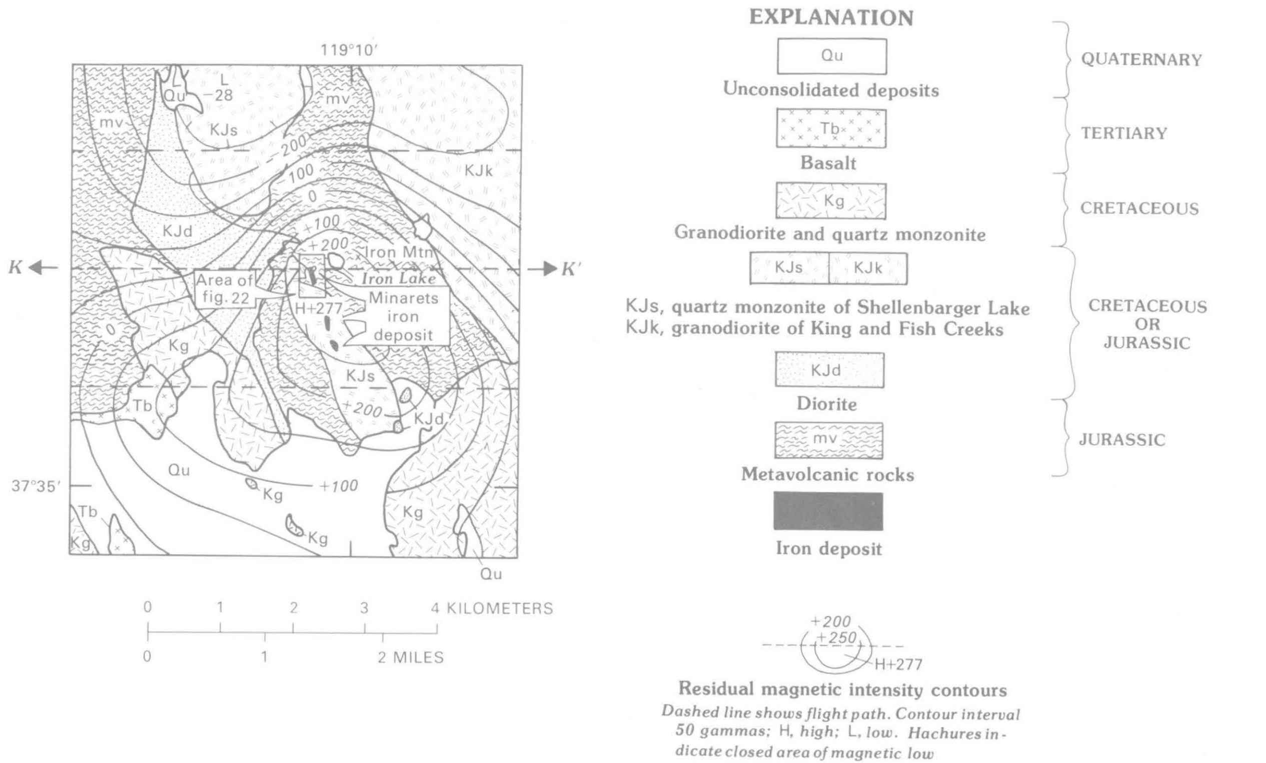


FIGURE 20.—Geologic and aeromagnetic map of the Minarets iron deposit and vicinity. Geology after Huber and Rinehart (1965a). See figure 21 for profile and cross section of flight path K–K′.

through *J* indicate that the deposit extends beneath the surface at least to profile *J* but narrows and plunges to more than 100 ft (30 m) below the surface. Nonetheless, the amplitude of the anomaly along *J-J'* is 18,000γ. Thus, the ground magnetic anomaly is 2,000 ft (600 m) long, 100 to 400 ft (30-120 m) wide, and averages about 50,000γ.

To determine whether the total aeromagnetic anomaly is caused by the iron deposits, an estimate of the effect of the ore body at flight elevations was made by approximating the ore body with such simple geometric forms as an infinitely long horizontal cylinder or a sphere. For example, an infinite horizontal cylinder at the surface with a vertical intensity of magnetization (J_t) of 1,300$\times 10^{-4}$ emu/cm^3 will cause an anomaly of 80,000γ with a half-width of

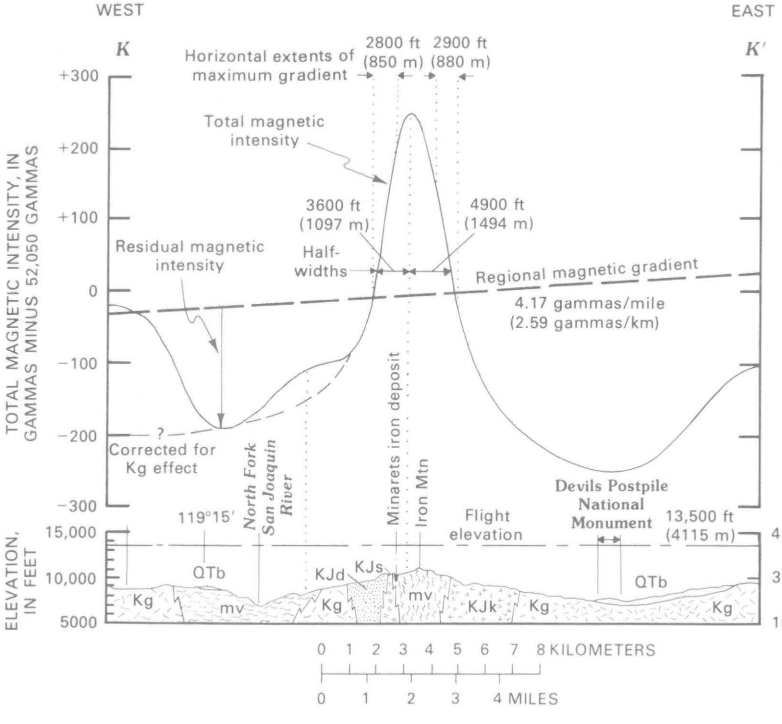


FIGURE 21.—Aeromagnetic profile and qualitative geologic cross section along *K-K'* (pl. 3, fig. 20). Aeromagnetic profile was traced from original analog record before regional magnetic field (IGRF) was removed and is thus slightly different from residual magnetic intensity map (pl. 3). Zero level on total intensity scale was taken as computed IGRF value at 14,000 ft (4,300 m) over the Minarets iron deposit, and so approximate comparisons between total intensity profile and residual map can be made. See "Explanation" on plate 3 and figure 20 for description of geologic symbols and units.

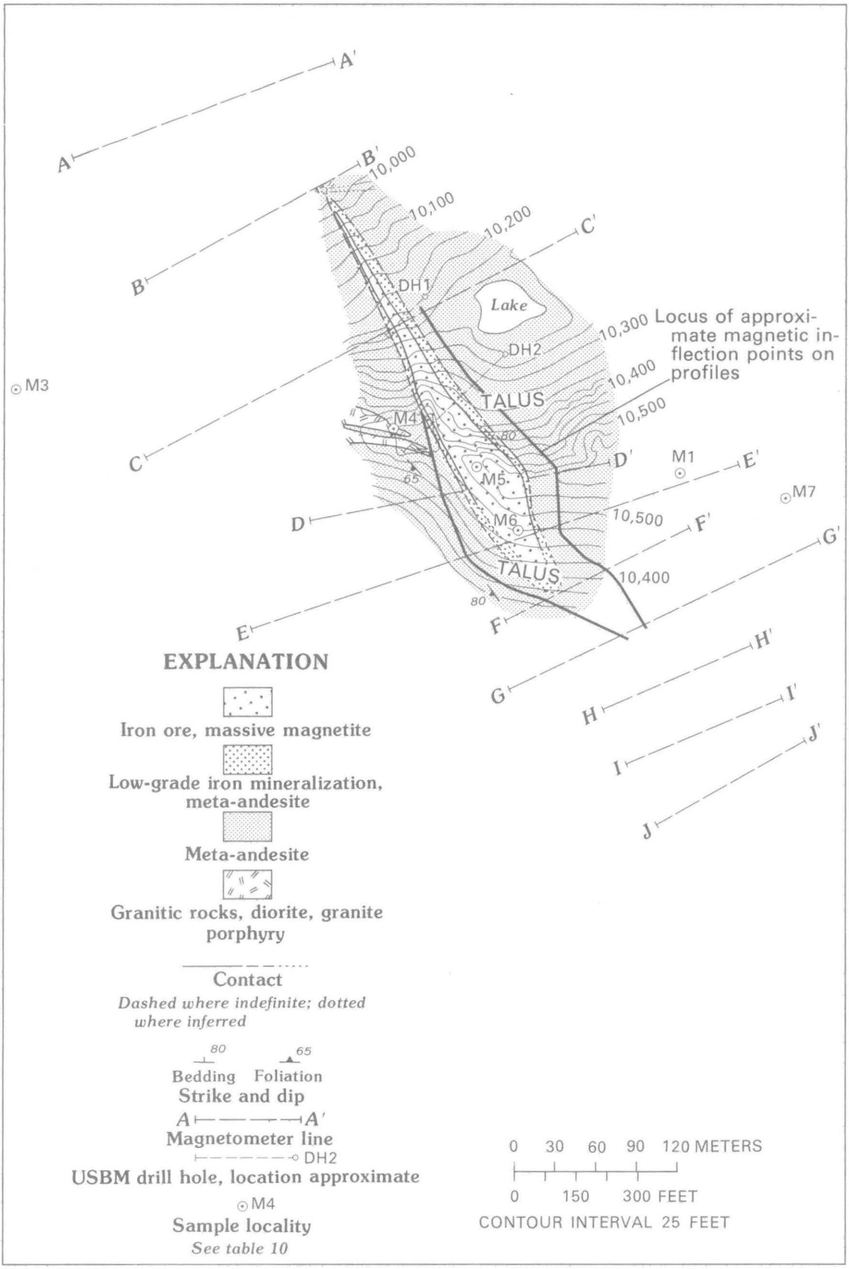


FIGURE 22.—Geologic map of the main Minarets iron deposit, and index of 10 ground magnetometer profiles *A-A'* to *J-J'*. See figure 20 for location. See figure 23 for profiles and interpreted sections along *C-C'* through *F-F'*.

TABLE 10.—*Densities and magnetic properties of rock sam-*

[Locations of samples near the Minarets iron deposit are shown in fig. 22; along Dana Fork (fig. 25) and Bloody from Oliver (1977, table 3) and apply to units in fig. 26.

Rock type	Specimen No.	Remarks	Density (g/cm³)
Minarets iron deposit and vicinity			
Iron ore	M5	~70% Fe_3O_4	4.74
	M6	~30% Fe_3O_4 with plagioclase.	3.63
Metavolcanic rocks	M1		2.78
	M3		2.88
	M7		2.75
Granitic rocks	M2		2.55
	M4		2.75
Area of Mount Gibbs anomaly			
Granitic rocks of the Cathedral Range intrusive epoch			
Granodiorite of Kuna crest		15 samples	2.74
Half Dome Granodiorite		24 samples	2.69
Cathedral Peak Granodiorite		2 samples	2.66
Dana Fork profile			
Felsic dike	G4		2.70
	G6		2.71
Quartz monzonite of Lee Vining Canyon	G9	Not oriented	2.61
	G10	do.	2.63
Metavolcanic rocks	G2	Tuff	2.70
	G3	Rhyodacite tuff	2.77
Metasedimentary rocks			
Black hornfels	G1	Collected in Dana Creek wall.	2.65
Arkosic sandstone	G7	Contains cordierite and epidote.	3.09
Pyrite-bearing hornfels	G7	Not oriented; 6-m erratic boulder from Mount Gibbs.	2.78
Bloody Canyon profile			
Diorite of Bloody Canyon	B17	Solid outcrop but brown stained.	2.68
	B15	Fresh	2.65
Quartz monzonite of Lee Vining Canyon	B4		2.64
Garnet-bearing aplite	B5		2.62
	B6	Not oriented	2.64
Autoliths in quartz monzonite of Lee Vining Canyon	B1	do.	2.73
	B18		?
Metavolcanic rocks			
Plagioclase-amphibolite	B10	Not oriented (float)	2.87
Epidote-amphibolite	B12	do.	2.80
Plagioclase-quartz amphibolite	B14	do.	2.79
Metasedimentary rocks			
Black hornfels	B7a		2.69
	B7b		2.69
Massive dark hornfels	B11		2.67

[1]For samples that are not oriented, the scalar sum of J_i and J_r are given in this column.

[2]This best value chosen is based primarily on the induced magnetization of sample M5. The sample is most typical of the ore; moreover, the Q values for iron ores are usually less than 0.5 (Cornwall, 1975), the high values and nearly horizontal directions in this area (see table 2) perhaps resulting from lightning strikes.

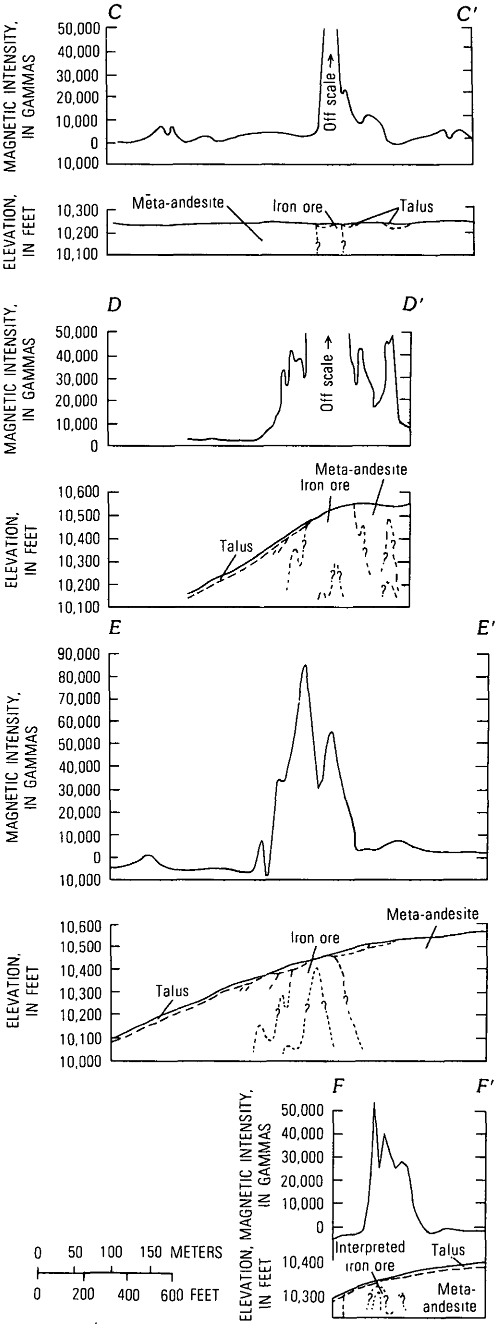
[3]Q-ratios above 10 are unusual for metavolcanic rocks, so samples M1 and M3 have probably been permanently magnetized by lightning. See scatter in the direction of J_r for these rocks (table 2). Similarly, the high Q-ratios for samples B10 and B7b raise doubts that these particular samples are representative of their respective rock types.

[4]This value undoubtedly too low because of the weathering out of some magnetite.

ples collected in the Minarets Wilderness area and vicinity

Canyon (fig. 27) profiles. Data on magnetic properties of granitic rocks of the Cathedral Range intrusive epoch All samples are oriented unless noted otherwise under "Remarks"]

Magnetic susceptibility (k) (10^{-4} emu/cm^3)	Induced magnetization (J_i=0.52k) (10^{-4} emu/cm^3)	Remanent magnetization (J_r) (10^{-4} emu/cm^3)	Koenigsberger ratio ($Q=J_r/J_i$)	Total magnetization: Vector sum[1] J_i+J_r (10^{-4} emu/cm^3)	Total magnetization: Best value for rock type (10^{-4} emu/cm^3)
7,500±2,000	3900	17,000±2,000	4.4	18,000	[2]4,000
3,100±200	1600	39,000±5,000	24.4	40,000	...
21	11	521	47[3]	525	[3]40
23	12	256	21[3]	260	...
17	8.8	28	3.2	30	...
2.0	1.0	...	...	...	...
.5	.3	?	...	...	1
10–40	5–20	1–7	.3–.4	6–30	20
20–38	10–19	2–6	.3–.4	12–25	20
18	9	2	.2	11	10
37	19	.3	.02	19	10±5
8.7	4.5	1.4	.31	4.8	...
5.1	2.6	<.1	<.02	2.6	2
<3	<1.5	...	...	...	...
2.2	1.1	<.1	<.01	1.1	1
.2	.1	<.1	<.1	.1	
.6	.3	1.7	5.8	1.6	Variable; 2–20 for all metasedimentary rocks.
44	23	.7	.03	22	
38	20	.7	.04	21	
.7	.4	.3	.7	.7[4]	50?
97	51	<.1	<.002	51	...
3.7	.19	<.1	<.5	<.3	.2
.9	...	<.1	<.1	.9	~1
.9	...	<.1	<.1	19	...
.3	...	<.1	<.3	.3	.3
.3	.16	.09	.6	.25	...
25.5	13.3	248	18.7	[3]261	Variable; 2–100 for all metavolcanic rocks.[3]
2.1	1.1	.8	.7	1.9	
58.2	30.3	95	3.1	120	
.4	.2	3.5	17	3	Variables; 0.2–3 for all metasedimentary rocks.[3]
.3	.2	19	[3]95	[3]19	
<.1	...	.1	>1	.2	



C
C'
MAGNETIC INTENSITY, IN GAMMAS
50,000
40,000
30,000
20,000
10,000
0
10,000
Off scale →
ELEVATION, IN FEET
10,300
10,200
10,100
Meta-andesite
Iron ore
Talus
D
D'
50,000
40,000
30,000
20,000
10,000
0
Off scale →
10,600
10,500
10,400
10,300
10,200
10,100
Meta-andesite
Iron ore
Talus
E
E'
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
10,000
10,600
10,500
10,400
10,300
10,200
10,100
10,000
Meta-andesite
Iron ore
Talus
F
F'
50,000
40,000
30,000
20,000
10,000
0
10,400
10,300
Interpreted iron ore
Talus
Meta-andesite
0 50 100 150 METERS
0 200 400 600 FEET

about 100 ft (30 m), and this anomaly approximates the observed ground magnetic anomaly in figure 23, section *E-E'*. The effect of an infinite horizontal cylinder drops off approximately as the square of the height above the cylinder, and the anomaly widens with increasing elevation (see table 12). At the flight elevation (3,300 ft [1,000 m] above ground), the anomaly is reduced to about 260γ and has a half-width of about 1,700 ft (500 m).

These calculations set an upper limit on the true effect of the iron deposit because the deposit is not infinitely long and its estimated depth is about two-thirds the height of 3,800 ft (1,160 m) to which the calculations were extended. For an estimate of the lower limit, similar calculations were made for a sphere; a sphere having a radius of 100 ft (30 m) and a magnetization of $10{,}000\times10^{-4}$ emu/cm^3 produces an effect of 80,000γ, as observed along profile *E-E'* (fig. 23). The magnetic effect of a sphere drops off as the cube of the height above the sphere to a value of about 20γ at 3,300 ft (1,000 m)

TABLE 11.—*Direction of remanent magnetization of oriented samples of magnetite-rich rock and metavolcanic rocks listed in table 10*

[See fig. 22 for location of samples]

Rock type	Specimen No.	Declination (D) (degrees)	Inclination[1] (degrees)	Remarks
(Induced magnetization—all rocks in Minarets area)		16	61	....
Magnetite-rich rocks	M5	21	19	Remanent vector nearly horizontal (±20°) with declination similar to Earth's field.
	M6	29	−18	
Metavolcanic rocks	M1	250	58	Large scatter
	M3	37	64	
	M7	164	−43	

[1]Negative numbers indicate reversed polarization.

TABLE 12.—*Magnetic effect of an infinitely long horizontal cylinder at various heights above the cylinder*

[Radius of cylinder is 200 ft (60 m), and vertical intensity of total magnetization (J_t) is $1{,}300\times10^{-4}$ emu/cm^3 (after Nettleton, 1940, p. 209-211)]

Height above cylinder (feet)	Vertical component of magnetic intensity (gammas)	Half-width of anomaly (feet)
0	81,681	96
200	20,420	192
800	3,267	480
1,800	817	960
2,800	363	1,440
3,300	267	1,680
3,800	204	1,920

FIGURE 23.—Ground magnetometer profiles and interpreted sections along *C-C'*, *D-D'*, *E-E'*, and *F-F'* (fig. 22). "Magnetic intensity" profiles were obtained with a Jalander magnetometer and represent variations in vertical component of Earth's magnetic field relative to an arbitrary datum. Both data and interpreted sections provided by a private exploration company.

and the anomaly widens to a half-width of 1,700 ft (500 m), or a bit wider than for the infinite cylinder.

On the basis of the above calculations, it is estimated that the main Minarets iron deposit has an average magnetization of about $5{,}000\times10^{-4}$ emu/cm^3 and an anomaly at the flight elevation of 13,500 ft (4,100 m) with a maximum intensity of 100–150γ and a half-width of about 1,700 ft (500 m). The intensity of magnetization obtained by simple geometric modeling of the ground magnetic data (fig. 23) is the same order of magnitude as that estimated from two sample measurements (table 10) and at the lower limit of the range 5,000–12,000 emu/cm^3 for the total magnetizations obtained from extensive sampling of similar ore bodies in Sweden (Cornwall, 1975). The remanent magnetization of the Swedish magnetite ores is generally weak, with *Q*-values between 0.1 and 1.0. The high remanent magnetizations measured for samples M5 and M6 of the main Minarets magnetite deposit (fig. 22; table 10) are nearly horizontal in direction (table 11) and are probably due to lightning strikes.

The purpose of the foregoing discussion of cylinders, spheres, magnetizations, and upward calculations of ground data was to determine whether the Minarets iron deposit causes or significantly contributes to the major aeromagnetic anomaly "H277" (pl. 3) shown in the section along *K–K′* (fig. 21). According to the calculations, the deposits contribute only about a fourth of the total intensity, and the half-width of the iron deposit anomaly is only about 40 percent of the observed half-width (3,600–5,000 ft [1,100–1,500 m] of the aeromagnetic anomaly (fig. 21). Thus, there must be an additional magnetic source that causes a broader anomaly of 325γ in amplitude. The evidence both from sample data (table 10) and from the aeromagnetic profiles immediately to the north and south of *K–K′* (pl. 3; fig. 20) suggest that the main source is the metavolcanic rocks themselves. Certainly, the best value of about 40×10^{-4} emu/cm^3 for the total magnetization of these rocks is sufficient to produce a 300γ anomaly at 3,300 to 4,300 ft (1,000–1,300 m) above the ground surface if the magnetization of the rocks extends to a depth of 10,000 ft (3,000 m) or more (see, for example, Oliver, 1972, pl. 1). Moreover, the next profile south of *K–K′* (fig. 20) does not cross over any known iron deposits and has nearly as high a maximum value (+230γ) as that along *K–K′* (+250γ) and an even larger half-width. The granitic rocks that crop out over a significant area within the +250γ magnetic closure (fig. 20) are relatively nonmagnetic (table 10), and the aeromagnetic data suggest that they become narrower at depth, similar to the teardrop structure of the granitic rocks of the Tuolumne Intrusive Suite in the eastern part of Yosemite National Park (Oliver, 1977, fig. 5). Geologic mapping during this and earlier studies (Trask and Simons, 1945; Huber and Rinehart, 1965a) of the area within the 250γ closure reveals that numerous small veins of magnetite occur within both the metavolcanic and granitic rocks, but important mineralization appears to be confined to the three major deposits (fig. 20). The aeromagnetic evidence and sampling data presented here suggest that the next step in future geophysical exploration for possible concealed iron deposits in this area should be ground or low-level (helicopter) magnetometry along the northwest-trending axis of the aeromagnetic high between profile *K-K′* and the flightline to the south.

MOUNT GIBBS MAGNETIC HIGH

It was shown above that most of the magnetic anomalies in the study area (pl. 3) are related to topography or to the more mafic metavolcanic and intrusive rock units. Notable exceptions are the Iron Mountain and Mount Gibbs magnetic highs (anomalies H and U, respectively, pl. 3). Both anomalies occur over metamorphic rocks near contacts with intrusive rocks, have residual amplitudes of 400-500γ, and have similar wavelengths. However, the metavolcanic rocks exposed at the surface beneath the Iron Mountain anomaly are known to be magnetic (table 10), whereas initial measurements of the magnetic properties of samples collected by Kistler (1966a, 1966b) indicated that the rocks under the Mount Gibbs anomaly are nearly nonmagnetic. Also, it is known that the Iron Mountain anomaly is partly caused by an iron deposit. In order to determine the significance of the Mount Gibbs anomaly, two ground magnetometer profiles were made, and about 30 oriented rock samples were collected and studied in an effort to find the rocks or minerals causing the anomalous magnetism.

The only aeromagnetic data on the Mount Gibbs anomaly are along the two flightlines to the north and south of the anomaly (pl. 3; fig. 24). The flightline to the north shows an increase of nearly 400γ over the Triassic granitic rocks at the west Wilderness boundary. Clearly, part of the anomaly is related to topography, although such anomalies do not occur over the Sierran crest to the north and south (pl. 3), and so the origin of the rest of the anomaly is in question.

A ground magnetic survey was made with measurements every 50 ft (15 m) approximately in line with the airborne survey, and oriented rock samples were collected from major geologic units. Figure 25 shows both the ground and airborne data along profile *M-M′* (fig. 24) and the locations of samples G1 through G10 for

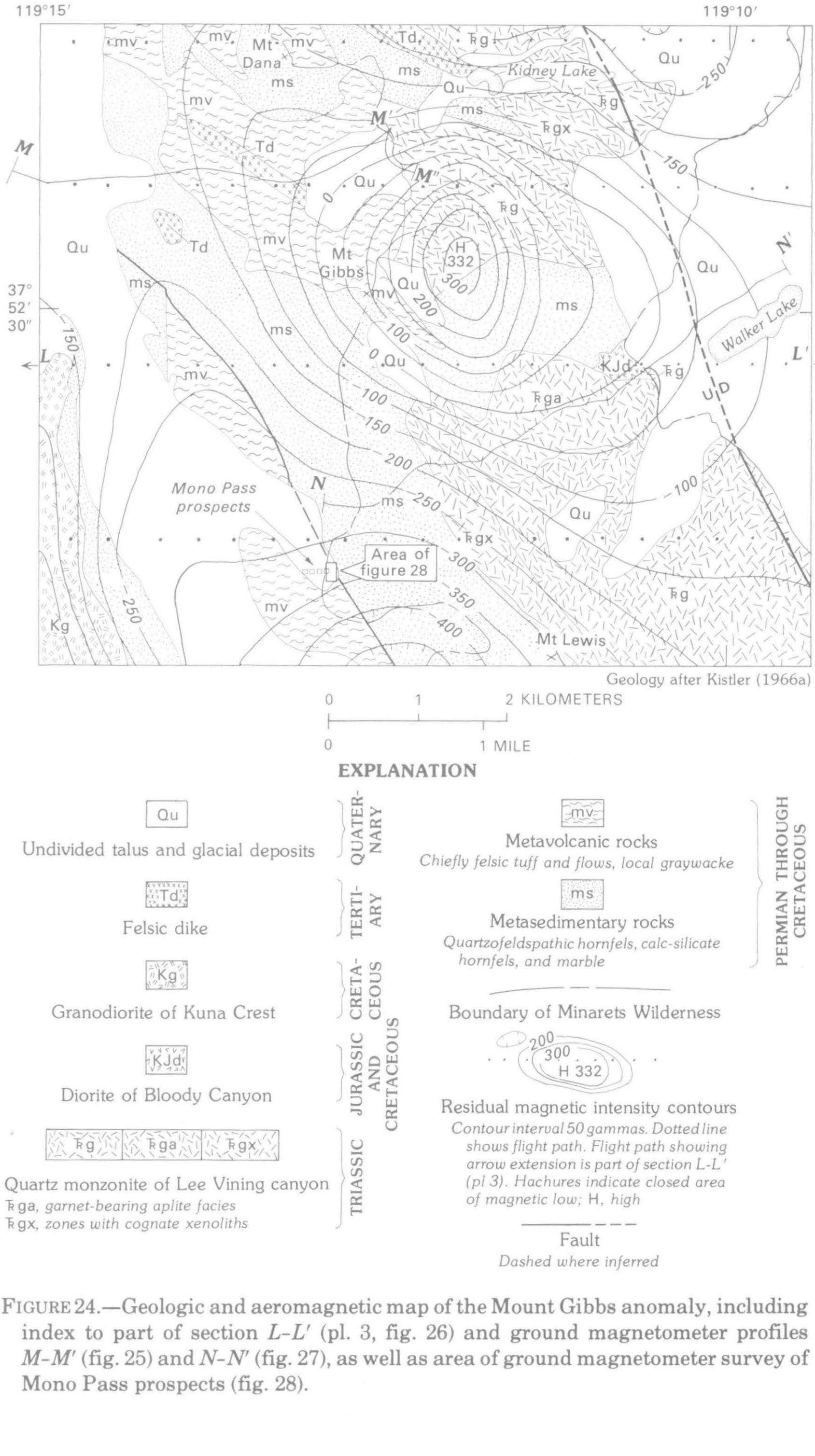


FIGURE 24.—Geologic and aeromagnetic map of the Mount Gibbs anomaly, including index to part of section *L-L′* (pl. 3, fig. 26) and ground magnetometer profiles *M-M′* (fig. 25) and *N-N′* (fig. 27), as well as area of ground magnetometer survey of Mono Pass prospects (fig. 28).

which magnetic properties were measured (see table 10 under "Dana Fork profile"). The measurements were made with a Geometrics proton-precession magnetometer, which is drift free and measures total magnetic intensity. Magnetic base stations D1 through D9, shown in figure 25, were remeasured to check for unusual diurnal changes, and values within ±20γ were obtained. The Castle Rock, Calif., and other magnetic observatory records show that no widespread magnetic storms occurred during our ground measurements. Therefore, the maximum error in the ground data is ±20γ, and adjacent readings should be accurate to ±2γ.

The ground magnetic data along profile *M-M′* (fig. 25) tend to substantiate the airborne data and show a general correlation with the magnetic high near the Sierran crest; however, the data indicate that the high in this area is not associated with the Triassic intrusive rocks but rather with a magnetic facies of metavolcanic rocks that crops out south of the talus deposits over

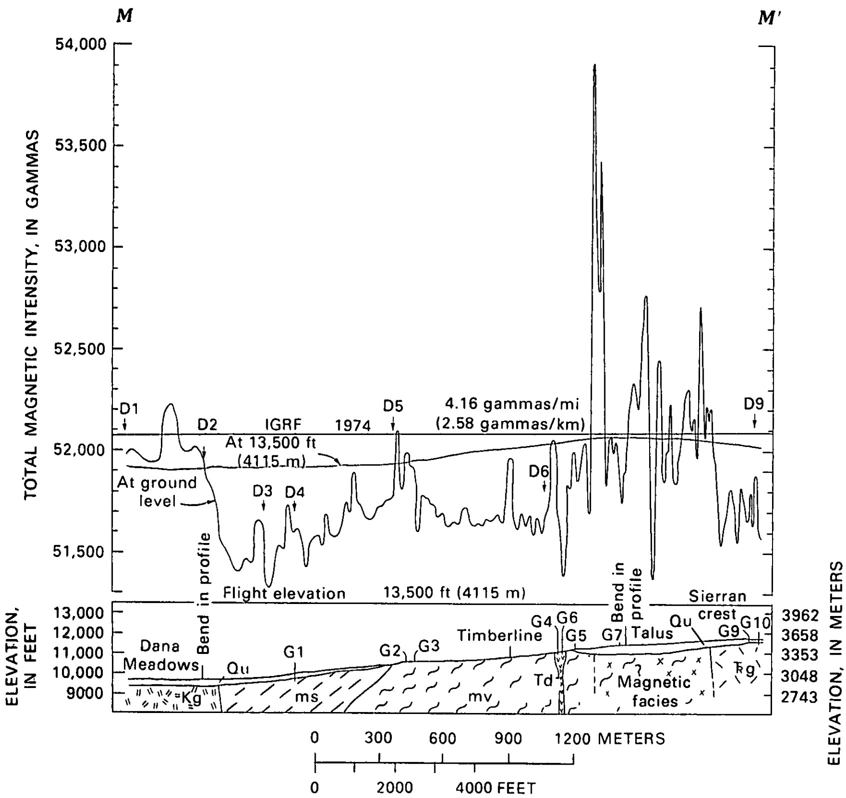


FIGURE 25.—Total-intensity ground magnetic survey and geologic section along *M-M′* (fig. 24). Locations of rock samples G1 through G10 (see table 10) for which magnetic properties were measured are shown along profile; D1-D9 indicate magnetic base stations. See "Explanation" in figure 24 for a description of geologic symbols and units.

which the high occurs (fig. 24). Laboratory measurements on the five samples collected also tend to indicate that some of the metavolcanic rocks are significantly more magnetic than the quartz monzonite of Lee Vining Canyon (table 10). Depending on the size and shape of the magnetic mass, a minimum magnetization of about 5×10^{-4} emu/cm^3 is required for a rock mass to cause even a small aeromagnetic anomaly, say, 50γ, at 1,000 ft (300 m) or more above ground. Rock units listed in table 10 with total magnetizations less than 5×10^{-4} emu/cm^3—such as the Triassic granitic rocks, most of the metasedimentary rocks, and some of the metavolcanic rocks—are not magnetic enough to cause significant aeromagnetic anomalies, and they produce local variations of less than 100γ at ground level (fig. 25). Ground magnetic data were also obtained from *M'* southeast along the Sierran crest and Wilderness boundary toward the center of the aeromagnetic anomaly as far as *M''* (fig. 24). The total magnetic intensities at ground level show little variation along *M'*-*M''* (±100γ) and do not correlate with the rise of about 150γ at the 13,500-ft (4,100 m) level indicated by the aeromagnetic map. Thus, these ground data cast some doubt on the validity of the interpolation between flight lines.

The aeromagnetic flightline that crosses the Wilderness area to the south of the interpolated center of the Mount Gibbs anomaly (H322, fig. 24) also rises from a background level of about −200γ and reaches a maximum value of about +100γ nearly 1 mi (1½ km) east of the Sierran crest (fig. 24). The original analog data for this profile have been traced, the IGRF removed manually (Leaton and Barraclough, 1971), and the data registered to the topographic profile and geologic section (fig. 26). This compilation was extended as far west as Tuolumne Meadows in Yosemite National Park so as to put the Mount Gibbs anomaly in perspective with adjacent features. The extension shows that there is another anomaly to the west with about the same amplitude as that in the Mount Gibbs area. The western anomaly is associated with those granitic rocks of the Cathedral Range known to be the most magnetic of the granitic rocks (table 10). The position of the maximum of the Mount Gibbs anomaly (labeled "Maximum" in fig. 26) has been checked by both strip-film and limited radar altimetry data, and it should be moved about 1,000 ft (300 m) to the east of its position in figures 24 and 26. This change places it closer to the contact between the metasedimentary rocks and the Triassic granite.

To quantitatively test the effect of topography on the observed profile, the cross section in figure 26 was digitized, and its effect computed using Talwani and Heirtzler's (1964) magnetic 2-D program as modified by M. C. MacKenzie. Rocks down to sea level

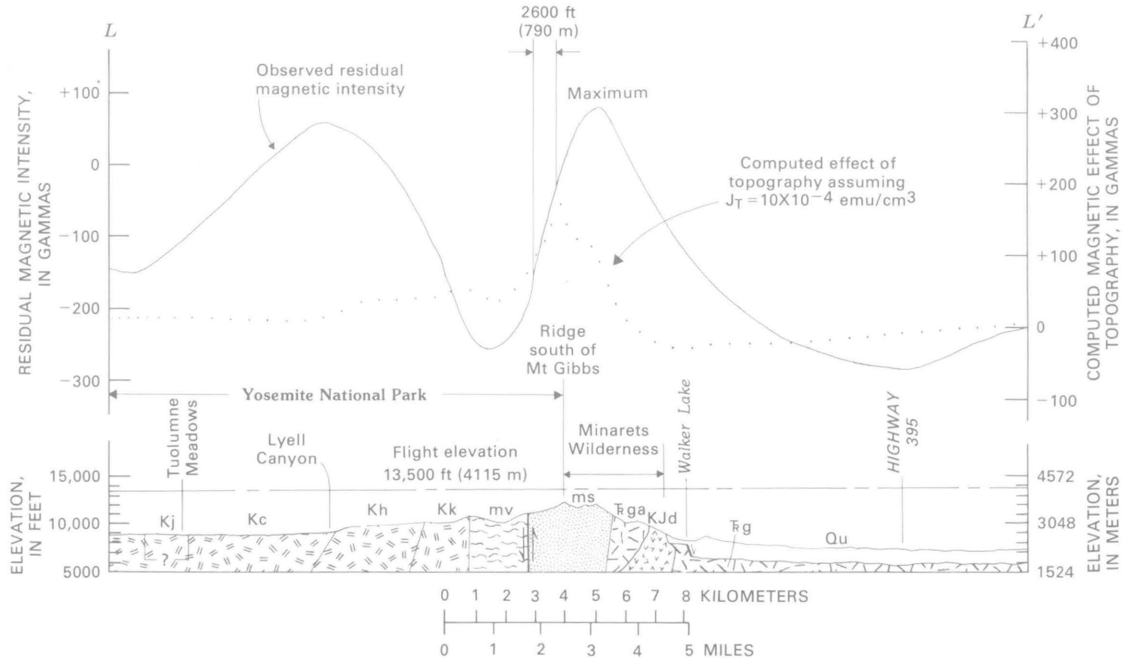


FIGURE 26.—Aeromagnetic profile, computed effect of topography, and qualitative geologic section along *L-L′* (pl. 3; fig. 24). See "Explanation" in plate 3 and figure 24 for description of geologic symbols and units. Granitic rocks of Cathedral Range (Kg) are further subdivided in section because of their distinctive magnetic properties as follows: Kj, Johnson Granite Porphyry; Kc, Cathedral Peak Granodiorite; Kh, Half Dome Granodiorite; Kk, granodiorite of Kuna Crest.

were assumed to be uniformly magnetized with a value of 10×10^{-4} emu/cm^3, a reasonable value for the most abundant granitic rocks in the Cathedral Range but probably too high for metasedimentary rocks and much of the metavolcanic rocks (see table 10). In fact, the metavolcanic rocks apparently are related to a magnetic low along this profile about 2 mi (3 km) west of the Wilderness area in Yosemite National Park (fig. 26). A comparison between the observed curve and computed points shows that a magnetization of about 20×10^{-4} emu/cm^3 is required for the metasedimentary rocks to produce an anomaly comparable to the 300γ observed anomaly, even if the observed anomaly were centered over the topographic high, which it is not. Moreover, the eastern tail of the observed anomaly drops off much more slowly than the computed points. Thus, the observed curve does not reflect topography but some magnetic mass that is quite different magnetically from the rocks mapped in this area (fig. 24). Judging from the 2,560-ft (780 m) horizontal extent of maximum gradient on the west flank of the anomaly, the magnetic mass is fairly close to the surface and perhaps crops out somewhere on the east flank of Mount Gibbs. The anomaly is too wide to be caused by any such magnetic mass as the Minarets iron deposit.

The closest accessible route near the Mount Gibbs anomaly, as recorded along flightline *L-L′* (figs. 24, 26), is the Bloody Canyon trail from Mono Pass to Walker Lake (profile *N-N′*, figs. 24, 27). Profile *N-N′* crosses under flightline *L-L′* at a mafic intrusive unit, the "diorite of Bloody Canyon" (Kistler, 1966a), and passes only 2/3 mi (1 km) south of the maximum of about +100γ recorded along *L-L′* (fig. 26). Ground magnetic data were obtained along this trail in a way similar to that described above for the Dana Fork profile *M-M′* (fig. 25). These ground data (fig. 27) confirm that the aeromagnetic high is centered over Triassic granitic rocks; however, the ground data show that the anomaly is very regional and not the result of a high-level coalescence of sharp magnetic features that might indicate concentrations of magnetite near the surface. The regional high appears to be associated with the west half of the garnet-bearing aplite facies of the quartz monzonite of Lee Vining Canyon. The magnetizations of two samples of this rock type, B5 and B6 (see locations, fig. 27), are less than 10^{-4} emu/cm^3 (table 10), which is virtually nonmagnetic. Thus, rocks exposed at the surface beneath the anomaly are not the source of the regional high, and there must be a magnetic body at a depth of about 5,250 ft (1,600 m) below this profile, judging from the horizontal extent of the maximum gradient on the west flank of the anomaly. An anomaly of about 500γ at ground level was found to be associated with the diorite of Bloody Canyon. Perhaps this diorite body is larger than

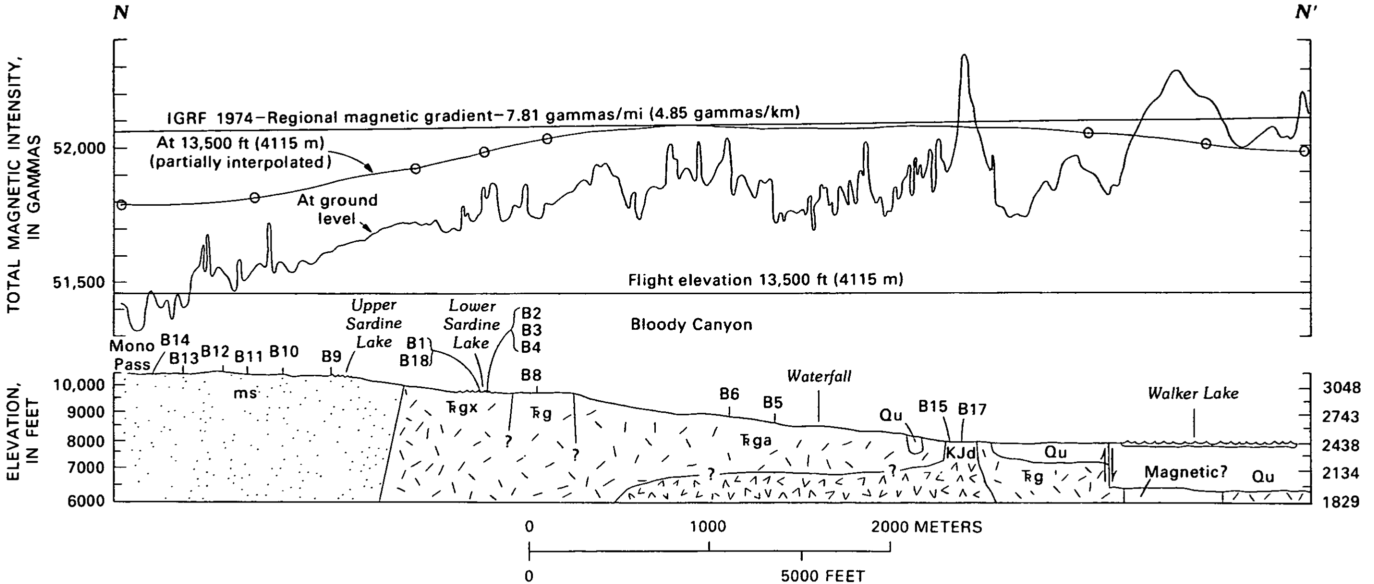


FIGURE 27.—Total-intensity ground magnetic survey and geologic section along *N-N'* (fig. 24). Locations of rock samples B1 through B17 (see table 10) for which magnetic properties were measured are shown along profile. See "Explanation" in figure 24 for description of geologic symbols and units.

the outcrop suggests and extends to the west under the Triassic aplite, as indicated schematically in figure 27.

Smaller magnetic anomalies of about 150γ are associated with areas of the Triassic granitic rocks that include 50 percent or more autoliths. Laboratory measurements of two biotite-rich autoliths collected near Lower Sardine Lake (samples B1 and B18, fig. 27) indicate that they are virtually nonmagnetic (table 10). Therefore the rock matrix of autolith-rich units must contain more magnetite than rock without autoliths.

In summary, the only magnetic rocks found by ground surveys in the vicinity of the Mount Gibbs anomaly are the metavolcanic rocks along profile *M-M′* and a diorite body along *N-N′* (fig. 24). Either one of these two units could account for the anomaly if it extended under the east flank of Mount Gibbs between aeromagnetic profile *L* and the profile 1 mi (1½ km) to the north. That the metavolcanic rocks would underlie this large area where Triassic granite crops out is unlikely. The westward extension of the diorite of Bloody Canyon is geologically more reasonable, although the fact that the aeromagnetic profile along *L-L′* passes directly over and is unperturbed by the diorite casts serious doubt on this hypothesis. Thus, there is some question whether the source rocks of the Mount Gibbs anomaly have been identified. If they crop out anywhere—and there is some reason to think that they do from the sharpness of the aeromagnetic anomaly along *L-L′* (fig. 26)—they might be found on the east flank of Mount Gibbs in the two cirques about 5,250 ft (1,600 m) east of Mount Gibbs at elevations of 11,000 to 12,000 ft (3,400-3,700 m). A magnetic survey of this area is beyond the scope of the present study.

MONO PASS MAGNETIC ANOMALY

A ground magnetometer survey was made of the Mono Pass prospects that are just inside the Minarets Wilderness area (fig. 24), to determine whether there is any magnetic expression of the buried sulfide-bearing zone. Stations were spaced about every 50 ft (15 m), covering an area about 650 by 3,000 ft (200 by 900 m). An elongate magnetic high of about 1,500γ was revealed (fig. 28), which encompasses the main shaft and several prospect pits, and whose long dimension is along the strike of a concealed bedrock fault exposed to the north and south of the glacial-moraine-covered area (fig. 24). Thus, there appears to be an association of magnetic material with the sulfide-bearing rock, and the magnetic anomaly may delineate the mineralized area. The 1,500γ, 200-ft (60 m)-wide anomaly at ground level is not manifest as even a minor wiggle on the aeromagnetic map (pl. 3; fig. 24), demonstrating the limitation of surveys flown with 1 mi (1½ km) spacing at constant elevation.

SIGNIFICANCE OF THE GEOPHYSICAL DATA

The regional gravity survey and a gravity profile across the

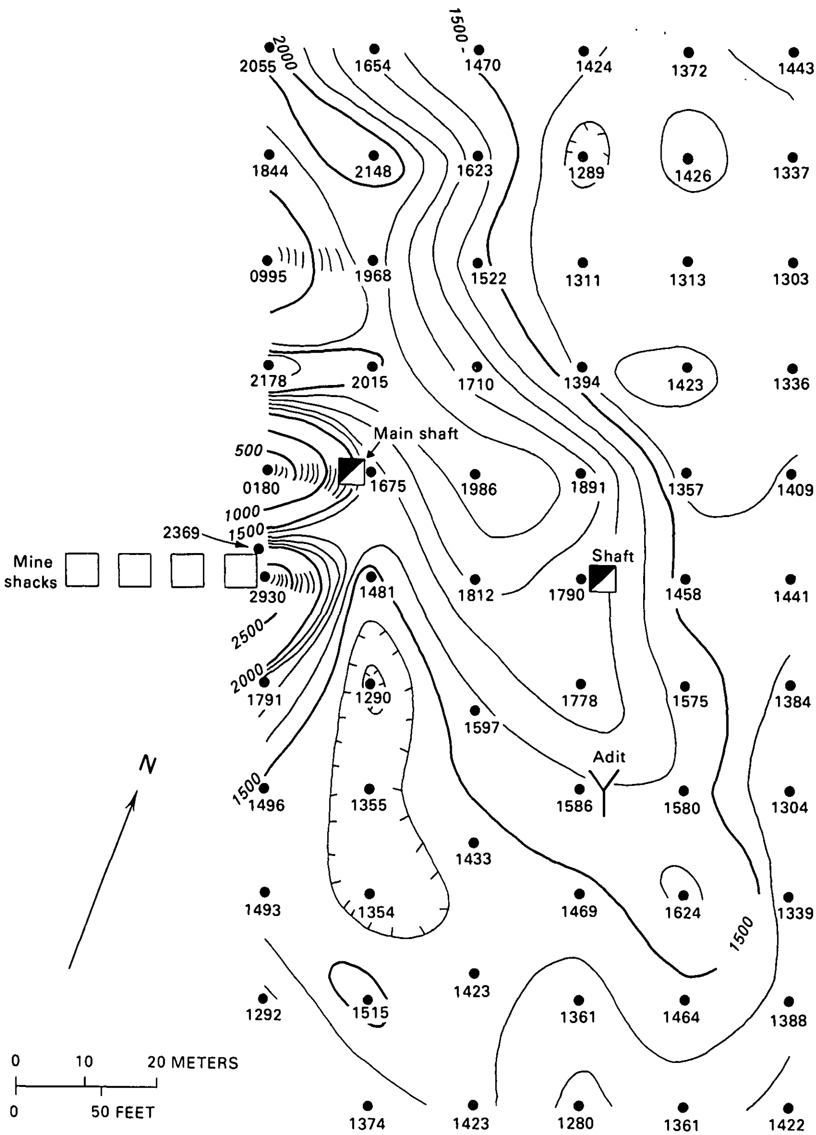


FIGURE 28.—Ground magnetic survey of Mono Pass prospects and vicinity. See figure 24 for location. Values plotted are total-intensity magnetic field minus 50,000 gammas. Contour interval, 100γ. Hachures indicate closed area of magnetic low.

north end of the study area did not reveal any gravity anomalies that might be related to mineral resources.

Although somewhat more detailed, the aeromagnetic survey is also regional in nature, and such a feature as the Mono Pass magnetic anomaly would have gone unnoticed had we not specifically investigated it with a ground magnetometer. Even the Minarets iron deposit with its 80,000γ ground-level anomaly might have gone undetected if a flightline did not pass directly over it. Tighter spacing—at least half that used—and lower level flights—within 2,000 ft (600 m) of the ground—are required to detect magnetic anomalies known to be associated with sulfide deposits, tungsten-bearing tactite deposits, and most iron deposits in the Sierra Nevada. We can conclude, however, that there are no serpentinite bodies such as those farther north that are associated with gold and silver, and no huge deposits of magnetite or pyrrhotite, because they would cause aeromagnetic anomalies of more than 1,000γ. Within the limited scope of the study, we were unable to find the source of a 400-500γ aeromagnetic anomaly over the east flank of Mount Gibbs, although computer analysis of topographic effects and the perspective of similar nearby anomalies that are caused by common rock types tend to diminish the Mount Gibbs anomaly's potential importance.

Geothermal-Resource Evaluation of the Minarets Wilderness and Adjacent Areas, Madera and Mono Counties, California

By ROY A. BAILEY, U.S. GEOLOGICAL SURVEY

MINERAL RESOURCES OF THE MINARETS WILDERNESS AND ADJACENT AREAS, MADERA AND MONO COUNTIES, CALIFORNIA

GEOLOGICAL SURVEY BULLETIN 1516-C

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GEOTHERMAL-RESOURCE EVALUATION OF THE MINARETS WILDERNESS AND ADJACENT AREAS, MADERA AND MONO COUNTIES, CALIFORNIA

By Roy A. Bailey, U.S. Geological Survey

INTRODUCTION

The Minarets Wilderness and adjacent areas covered in this report are situated along the crest of the Sierra Nevada immediately west of the Mono-Long Valley Known Geothermal Resource Area (KGRA) (fig. 29). Although very little of the study area is within the KGRA proper, much of the east margin of it is included within lands classified as "prospectively valuable" (see fig. 29; Godwin and others, 1971). In this report, these lands are shown to have little or no geothermal potential. Nowhere in the study area do features occur that suggest anomalously high near-surface heat flow. Neither does the study area contain any active or recent volcanism, hot springs, or fumaroles. It is only the general proximity of the study area to the Mono-Long Valley KGRA which suggests that it might have any geothermal potential at all.

In contrast, the nearby Mono-Long Valley KGRA includes some of the youngest rhyolitic volcanoes in the Western United States, as well as numerous associated hot springs and fumaroles. The area was recently studied intensively by the U.S. Geological Survey as part of its Geothermal Research Program and is currently under investigation by commercial interests for possible geothermal development.

The following evaluation of the geothermal potential of the study area is based mainly on recent U.S. Geological Survey studies of the Long Valley area, supplemented by new data collected from "prospectively valuable" lands adjacent to the study area. The report draws heavily on the results of my own geologic mapping (Bailey, 1974; Bailey and others, 1976; Bailey and Koeppen, 1977),

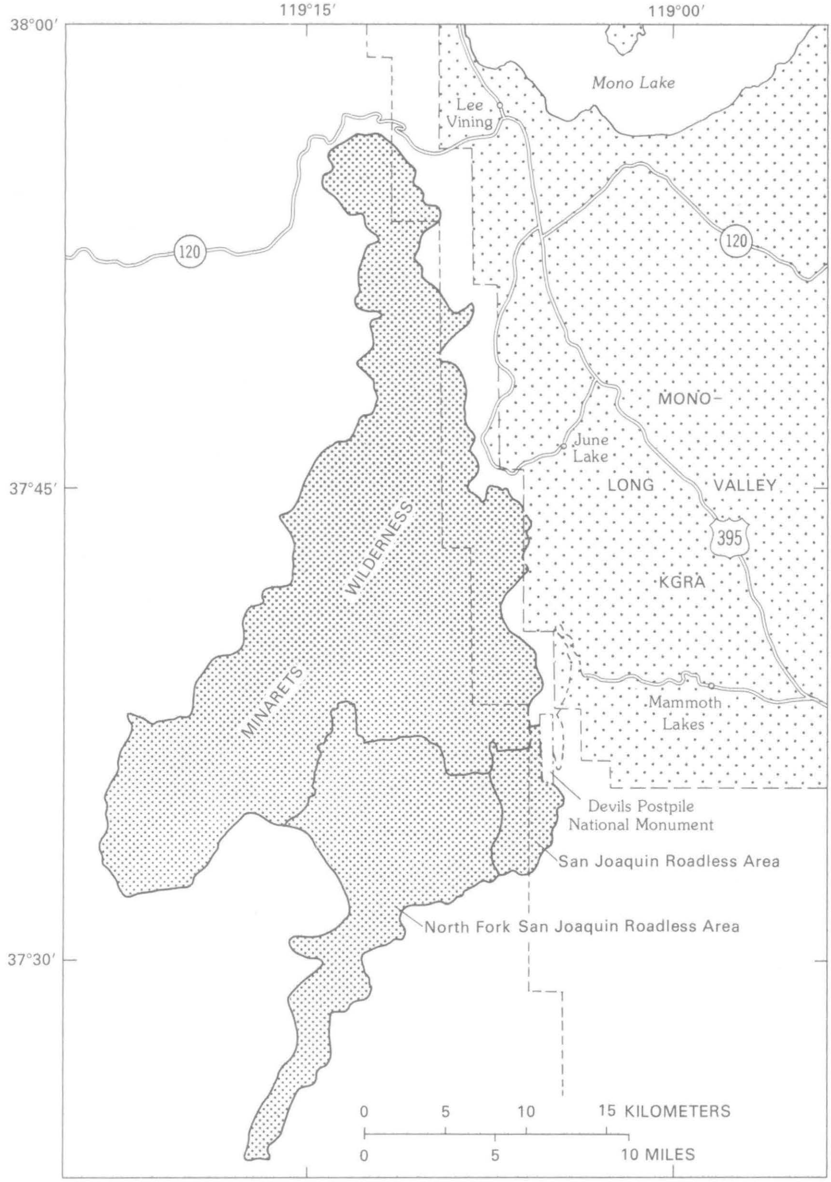

FIGURE 29.—Minarets Wilderness and adjacent study areas (fine stipple) and southwestern part of Mono-Long Valley Known Geothermal Resource Area (KGRA) (coarse stipple). Lands east of short-dashed line adjacent to KGRA are classified as "prospectively valuable" geothermal resources (Godwin and others, 1971).

as well as on gravity and aeromagnetic studies by Kane, Mabey, and Brace (1976) and Williams, Berkman, and Mankinen (1977), seismic-refraction studies by Hill (1976), heat-flow studies by Lachenbruch, Sass, Monroe, and Moses (1976), hydrology and water chemistry by Sorey and Lewis (1976) and Mariner and Willey (1976), and teleseismic studies by Steeples and Iyer (1976). The analyzed water samples reported in table 13 were collected by Larry Wade, U.S. Forest Service, and the respective equilibration temperatures were calculated by J. M. Thompson. The locations of several previously unrecorded cold carbonate springs in the study area were supplied by D. L. Peck and R. S. Fiske. Interpretation of the gravity and aeromagnetic data was greatly facilitated by new gravity information provided by D. L. Williams, and by discussions with H. W. Oliver and N. K. Huber.

GENERAL ASSUMPTIONS

Most large geothermal systems of the world are directly or indirectly associated with centers of relatively young volcanic activity. For this reason, the age, distribution, and general geology of the volcanic rocks within any area of prospective geothermal value are of primary consideration. Some of the basic assumptions on which evaluation of igneous-related geothermal systems is based were outlined by Smith and Shaw (1975). In brief, mafic lavas (basaltic to andesitic magmas) are assumed to form in the mantle and rise to the surface through relatively narrow fissures and pipes. The lavas seldom form large upper-crust magma chambers; thus, they usually do not directly contribute substantial amounts of heat to the upper part of the crust. In contrast, silicic lavas (dacitic to rhyolitic magmas) are assumed to originate at shallower depths, most likely in the lower crust, and commonly form large magma chambers in the upper part of the crust. These large silicic chambers are capable of storing large amounts of heat for long periods of time; thus, areas or regions in which such large heat sources occur, or are thought to occur, are of greatest economic interest.

The geothermal evaluation of such an area as the Minarets study area, which is adjacent to an area of large magmatic heat sources, requires a knowledge of the age, volume, and depth of these heat sources, the physical properties (conductivity, heterogeneity, and so on) of the surrounding country rock, and the general configuration of the hydrologic system. The geothermal potential of any such area is dependent primarily on its proximity to the heat sources and on the presence of rock bodies or structures with sufficient porosity and permeability to serve as natural reservoirs from which hot fluids can be extracted.

The general plan of this report is (1): to describe briefly the several episodes of Cenozoic volcanism in the general region of the study area and to discuss their relative importance in terms of heat sources, (2) to describe the nature and distribution of the thermal springs in the region and discuss their possible relation to heat sources, (3) to describe and discuss the available heat-flow, gravity, and aeromagnetic data in the vicinity of the study area, and (4) to discuss the physical properties of the Sierran bedrock as geothermal -fluid reservoirs.

VOLCANISM

GENERAL STATEMENT

The general geology of the study area is described in Chapter A of this volume; only the geology of the Cenozoic volcanic rocks of the region will be considered in detail here.

The pre-Cenozoic rocks of the Sierra Nevada consist mainly of Mesozoic plutonic rocks, which constitute the Sierra Nevada batholith, and of Paleozoic and mesozoic metasedimentary and metavolcanic rocks, which constitute roof pendants within the batholith. Although the individual plutons of the batholith were initially molten magma chambers, the youngest of them is about 80 m.y. old, and they have long since cooled and congealed and were uplifted and deeply eroded before emplacement of the younger volcanic rocks described herein. The initial heat content of the batholithic rocks has been entirely dissipated, and these rocks no longer contribute to the present near-surface geothermal regime. Surface heat flow in Seirran batholithic terranes is, in fact, unusually low, ranging from 0.45 to 1.3 heat-flow units (HFU) (Lachenbruch, 1968; Lachenbruch and others, 1976); it is against this background that local anomalies in the heat flow must be compared.

Cenozoic volcanism in the general region of the study area may be divided into three distinct episodes: (1) a Tertiary episode of widespread basaltic volcanism in the high Sierra, (2) a Quaternary rhyolitic episode centered about the Long Valley caldera, and (3) a late Quaternary basalt and rhyolite episode localized along the east Sierran frontal fault system.

TERTIARY BASALTIC EPISODE

Widely scattered over the Sierra Nevada in the general vicinity of the study area are many small basaltic plugs, dikes, and associated patches of basaltic lava (fig. 30). Most of the plugs are but a few tens of meters in diameter, and the dikes are seldom more than a few hundred meters long. These dikes and plugs, many of which were vents for the lavas, are scattered apparently randomly over an area greater than 1,000 km^2 mainly east and south of the study area. The individual lava patches generally do not exceed 5 km^2 in

FIGURE 30.—Distribution of Tertiary and early Pleistocene volcanic rocks in vicinity of study area. Tertiary basaltic rocks, solid black; Quaternary rhyolitic and quartz latitic rocks associated with Long Valley caldera, stippled. Dotted line is outline of Long Valley caldera.

area, and most are much smaller; though somewhat reduced in extent by erosion, they probably did not greatly exceed their present extent. Their total area is, and probably initially was, less than 100 km^2. The most extensive (25 km^2) and thickest (300 m) accumulation of basaltic lava occurs in the vicinity of San Joaquin Mountain, where related locally thick quartz latite lava also occurs (Huber and Rinehart, 1967).

The basaltic and minor quartz-latitic rocks of this Tertiary episode intrude and uncomformably overlie the Cretaceous plutonic and older metamorphic rocks of the Sierra Nevada; the lava bodies commonly rest on erosional surfaces or fill canyons cut during uplift of the range. K-Ar dating (Dalrymple, 1963) indicates that most of these basaltic rocks were erupted between 3.6 and 2.6 m.y. ago, although some are as old as 9 m.y.

EARLY PLEISTOCENE RHYOLITIC EPISODE OF LONG VALLEY

The Pleistocene volcanic and structural evolution of the Long Valley caldera has been described by Bailey, Dalrymple, and Lanphere (1976) and will only be briefly summarized here.

Beginning about 1.9 m.y. ago and continuing until about 0.1 m.y. ago, vast volumes (>700 km^3) of rhyolitic lava and pyroclastic rocks recurrently erupted in the vicinity of Long Valley from a 20-km-diameter magma chamber that rose to within 5–8 km of the surface. The initial eruptions from this chamber took place between 1.9 and 0.9 m.y. ago and built a large complex of rhyolite domes, flows, and pyroclastic rocks, some of which are now exposed at Glass Mountain, northeast of Long Valley.

About 0.7 m.y. ago, cataclysmic eruptions of ash and pumice, mainly in the form of ash flows, removed 600 km^3 of magma from the upper part of this chamber, causing its roof to collapse and thereby forming the 20- by 30-km elliptical depression of the Long Valley caldera (fig. 30). The resulting ash-flow deposits, which constitute the Bishop Tuff (Gilbert, 1938; Sheridan, 1965; Hildreth, 1979), cover an area of 900 km^2 surrounding the caldera. Subsequent volcanism was confined within the west half of the caldera and consisted of intermittent eruption of rhyolite and quartz latite domes and flows between 0.67 and 0.05 m.y. ago. During the early and middle stages (0.7–0.1 m.y. ago) of postcaldera activity, the lavas were rhyolitic and confined to the caldera floor; during the late stage (0.18–0.05 m.y. ago), they were quartz latitic and localized on the margins and rim of the caldera. The largest accumulation of these younger quartz latite eruptive rocks forms Mammoth Mountain on the southwest rim of the caldera (fig. 30).

LATE PLEISTOCENE AND HOLOCENE BASALT-RHYOLITE EPISODE

The rhyolitic volcanism of the Long Valley caldera was overlapped and followed by an episode of volcanism that began with basaltic eruptions about 0.2 m.y. ago and continued with rhyolitic eruptions until at least 725 years ago. The basaltic eruptions were localized on north-south-trending echelon fissures extending 40 km along the faulted east front of the Sierra Nevada from Devils Postpile to Mono Lake (fig. 31). The bulk of this basalt was erupted between 0.2 and 0.06 m.y. ago from centers in the Devils Postpile area and in and adjacent to the west moat of the Long Valley caldera, which was filled to a depth of at least 100 m with basaltic lava. Other, somewhat younger centers erupted at June Lake between 60,000 and 20,000 years ago and at Black Point on the north shore of Mono Lake 13,300 years ago (Lajoie, 1968).

Approximately parallel to and slightly east of this trend of basaltic volcanism is a chain of rhyolitic centers (fig. 31). These include, from south to north, the Inyo Craters, the Mono Craters, and the volcanic islands of Mono Lake—Paoha, Negit, and several other small unnamed islets. The largest accumulation of rhyolite is that of the Mono Craters, a 14-km-long chain of 22 coalesced rhyolite domes and coulees ranging in age from 1,000 to about 40,000 years (Dalrymple, 1967; Wood, 1977). This chain forms a convex-eastward arc that is concentric with a 12-km-diameter circular mylonite zone (Kistler, 1966b) and a related arcuate fault system (Bailey and others, 1976). These relations strongly suggest that the Mono Craters erupted from an incipient ring fracture above an actively rising magma chamber.

The Inyo Craters are a discontinuous chain of five rhyolite domes, apparently erupted from a fissure extending 10 km south of the Mono Craters to the northwest corner of the Long Valley caldera. Carbon-14 dating (Wood, 1977) indicates that one of these domes is as young as 725 years.

The volcanic islands in Mono Lakes, which range in composition from rhyolitic to rhyodacitic, have not been dated radiometrically but are probably no older than 2,000 years and may be as young as 500 years.

DISCUSSION

Each of the above volcanic episodes was a thermal event that affected to differing degrees the thermal regime of the crust in the vicinity of the study area. The Tertiary basaltic episode 9–3 m.y. ago, though the most widespread and the only one with eruptive centers within the study area itself, probably had only a minor effect on the thermal regime in the upper-crust. The small size and dispersed distribution of the centers, together with the small volume of lavas erupted, suggest that only a relatively small volume of basaltic magma reached upper crustal regions from its probable

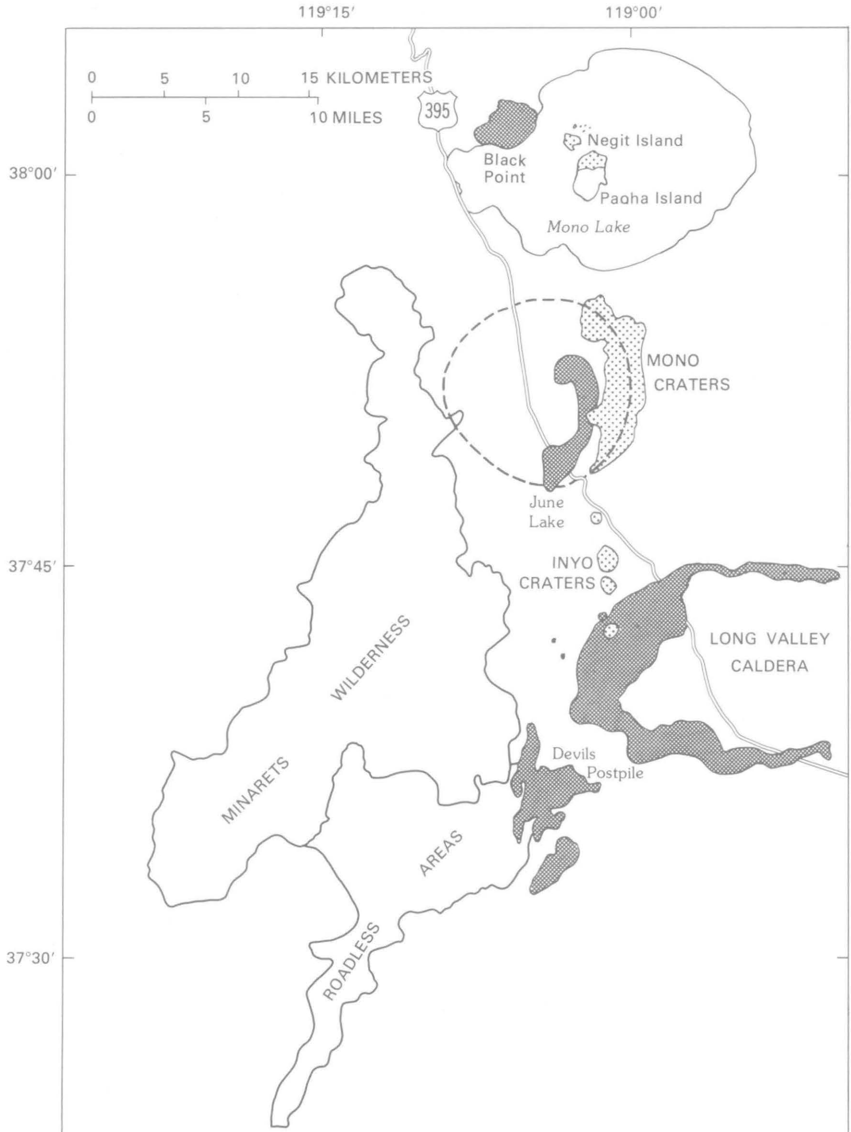

FIGURE 31.—Distribution of late Pleistocene and Holocene volcanic rocks near study area. Basaltic rocks, solid black; rhyolitic rocks, stippled. Dashed circle shows approximate location of Mono Craters ring fracture.

source in the mantle. Furthermore, the minimum established age of 2.6 m.y. for these small centers indicates that the heat associated with them has long since dissipated and that they do not contribute to the present upper-crustal thermal regime. Surface heat-flow measurements in areas where basaltic centers of this age occur are not expected to exceed the low average values typical of Sierran granitic terranes (see Diment and others, 1975; Sass and others, 1976).

The large volume of Pleistocene rhyolitic ejecta associated with the Pleistocene Long Valley caldera and the size of the caldera provide a measure of the size of the Long Valley magma chamber at the time of eruption of the Bishop Tuff 0.7 m.y. ago. Geologic information (Bailey and others, 1976), gravity studies (Kane and others, 1976), and heat-flow studies (Lachenbruch and others, 1976) suggest that the precaldera Long Valley magma chamber was a roughly cylindrical body, about 20 km in diameter, that extended from within 5 km of the surface to an unknown depth and that it possibly included a laccolithic or tonguelike offshoot extending 10 km eastward in its upper 3 or 4 km. The volume of this chamber above an arbitrary depth of 15 km is estimated to have been about 3,000 km^3. Thermal calculations (Lachenbruch and others, 1976) and my own unpublished petrologic studies suggest that after eruption of the Bishop Tuff, most, if not all, of the magma remaining in the chamber crystallized during the ensuing 0.7 m.y. However, teleseismic studies of the Long Valley caldera (Steeples and Iyer, 1976) and seismic-refraction studies (Hill, 1976) indicate that a low-velocity zone, 14 km in diameter and extending from 7–8 to possibly 15 km depth, presently exists beneath the caldera. On the basis of presently available data, it is not known whether this low-velocity zone is due to the presence of partially molten residual magma or to a still-hot crystalline core. In either case, it is likely that the central third (about 1,000 km^3) of the chamber remains at near-solidus temperatures (650°–700°C). This large volume of hot rock (or magma) is the obvious heat source for the surface hydrothermal activity within the Long Valley caldera (Sorey and Lewis, 1976). However, thermal calculations based on the work of Lachenbruch, Sass, Monroe, and Moses (1976) suggest that in spite of its proximity to the study area, a magma chamber beneath the Long Valley caldera could contribute little to conductive surface heat flow within the study area.

Similar calculations for heat flow related to the inferred Holocene magma chamber beneath Mono Craters, on the northeast edge of the study area (fig. 31), indicate that the chamber is probably too young and as yet too deep to have affected near-surface heat flow (Lachenbruch and others, 1976, p. 781); furthermore, assuming that its depth is beween 5 and 10 km below the surface, it may be another 50,000 to 100,000 years before heat from the chamber will significantly affect near-surface heat flow in any part of the study area.

Thus conductive heat flow from neither of the major heat sources in the vicinity of the study area appears to be sufficient to indicate that lands within the study area are prospectively valuable as geothermal resources.

THERMAL SPRINGS

No fumaroles, hot springs, or other hydrothermal features suggestive of high heat flow occur within the study area. The nearest fumaroles are on Mammoth Mountain, 6 km southeast of the study area, and a single group of thermal springs (T<80° C) occurs at Reds Meadow, 2 km southeast of the study area (fig. 32, No. 6). Within the study area are several cold carbonate springs, possibly indicative of former mild thermal activity, as well as innumerble cold freshwater springs. A number of these carbonate springs were visited and described by Waring (1915). Although none were revisited for the present study, new data from similar cold carbonate springs near the southeast boundary of the study area were obtained (table 13). New data for Reds Meadow Hot Springs, also described by Waring, were also collected.

Reds Meadow Hot Springs is at Reds Meadow Campground, 1.2 km southeast of Devils Postpile at an elevation of about 2,530 m. Waring (1915, p. 54, 380) recorded five small springs having a total flow of about 40 L/min (10 gal/min). The largest of these springs he described as excavated in a small deposit of calcium carbonate (travertine) being formed by the spring. This largest spring is presently channeled into a small bathhouse maintained by the U.S. Forest Service for the benefit of campers and hikers. Waring recorded a temperature of 49° C, which compares favorably with a 1974 measurement of 47°C. Waring's chemical analysis of the water (table 13, a) compares well with a more recent analysis (table 13, b). Table 13 also contains recent analyses of two nearby cold carbonate springs, analyses of two nearby meteoric waters, and the range in composition of hot-spring waters in the Long Valley caldera.

The Reds Meadow Hot Springs waters, compared with those of Long Valley caldera, are appreciably lower in boron, fluorine, chlorine, and lithium, indicating that these elements, usually indicative of thermal waters, are strongly diluted by meteoric water at Reds Meadow. Even lower concentrations of these elements are present in the cold carbonate spring waters, but they are generally

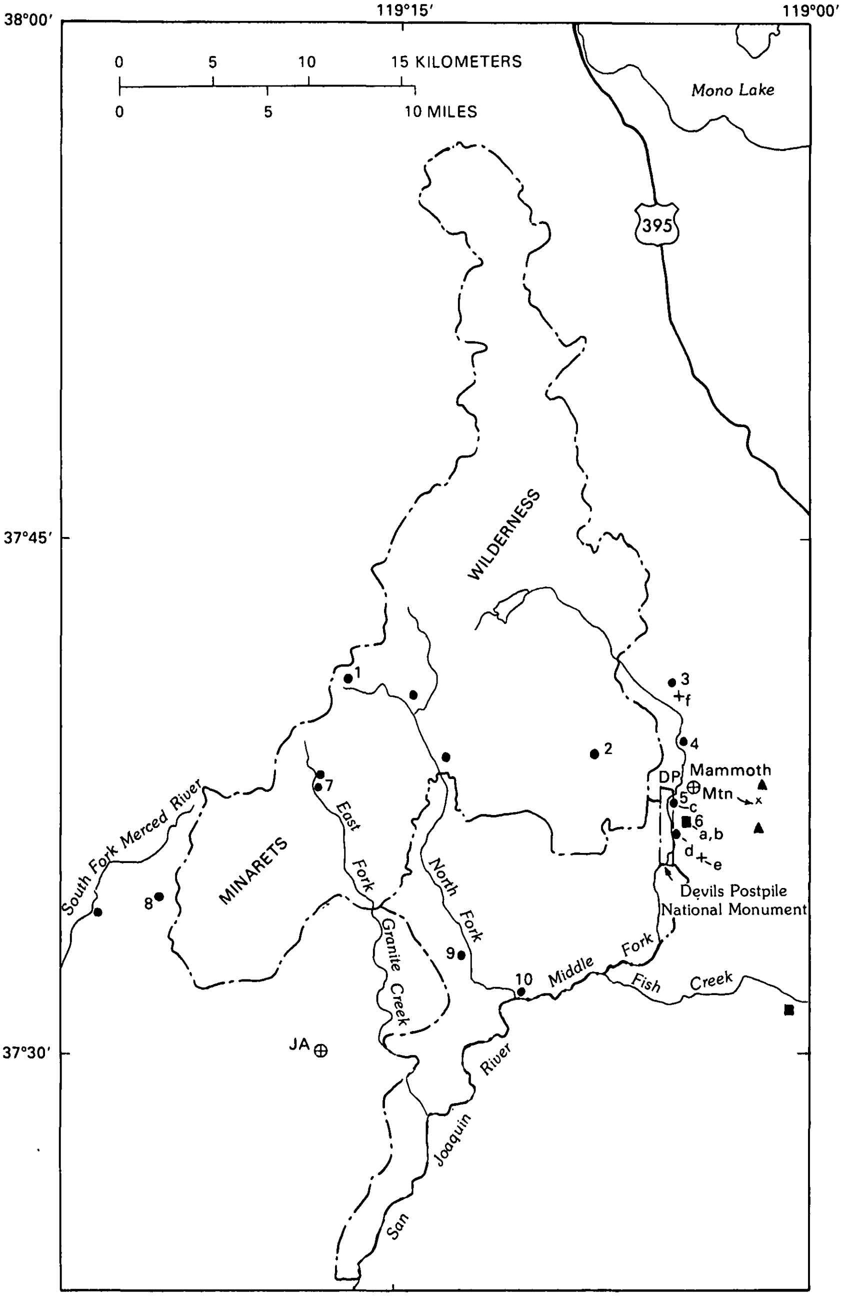

FIGURE 32.—Location of fumaroles (triangles), hot springs (squares), cold carbonate springs (circles), and meteoric-water samples (crosses) in and near study area. Numbers refer to Madera County spring numbers of Waring (1915). Letters refer to analyzed waters listed in table 13. Circled crosses show locations of drill holes DP and JA (Lachenbruch and others, 1976).

TABLE 13.—*Composition of thermal and meteoric waters from areas near the study area*

	Hot springs			Carbonate springs		Meteoric waters	
	Reds Meadow		Long Valley caldera[1]	Soda Spring, Devils Postpile	Near San Joaquin River Devils Postpile	South Boundary Creek	Agnew Meadow
Locality, fig. 32	a	b		c	d	e	f
Year	1915	1974	1972-1974	1974	1974	1974	1974
T°C	49°	47°	49-94°	12°	10°	7°	5°
pH	--	7.3	6.5-9.2	7.3	8.2	6.7	6.9
Discharge, L/min	40	340	100-400	700	170	5950	2550
SiO_2	133 ppm	152 ppm	110-340 ppm	79.4 ppm	83.6 ppm	59.4 ppm	30.2 ppm
Ca	62	22	16-50	56	13.5	7.5	49
Mg	3.3	2.0	.1-1.2	25.5	29	6.8	23
Na	140	143	310-410	580	208	14.3	2
K	6.4	6.3	22-45	24.5	13.7	4.4	1
Li	--	.87	1.5-2.8	2.06	.55	.04	<.02
HCO_3	243	523	416-828	1240	716	84	46
SO_4	36	35	59-130	40	17	4	2.7
Cl	12	5.6	150-280	332	17	<.4	<.2
F	--	.4	4.6-12	.17	.58	<.1	<.1
B	--	1.8	7.7-15	7.7	25	<.1	<.1

[1]Range of values for Long Valley hot springs from Mariner and Willey (1976, table 1).

higher than the background concentrations indicated by the meteoric waters. The presence of these elements, even in small amounts, in the Reds Meadow and the cold carbonate springs suggests that their waters are mixtures of deep high-temperature water and cold near-surface meteoric water. Under certain limiting conditions (Fournier and Truesdall, 1974; Fournier and others, 1974) it is possible to calculate the temperature and fraction of the hot-water component in such mixed spring waters; however, because of their low flow rates and the absence of associated fumaroles, such calculations for the Reds Meadow and carbonate springs (table 14) probably are of questionable validity (J. M. Thompson, written commun., 1976). Also, because the Reds Meadow Hot Springs as well as the carbonate springs are actively depositing calcium carbonate, equilibration temperatures of the hot-water component based on the Na-K-Ca geothermometer are probably anomalously high (Fournier and Truesdell, 1973, p. 1271). The general disagreement between the equilibration temperatures indicated by other available geothermometers (table 14) suggests that all the calculated temperatures are questionable. However, the range of temperatures shown by the geothermometers may be broadly interpreted as indicating that the hot-water component probably does not exceed 120°-160°C. Independent calculations by Mariner, Presser, and Evans (1977, p. 23) based on somewhat different assumptions suggest that the temperature of the hot-water component may be as low as 64°-66°C. Although chemical data are not available for the cold carbonate springs within the study area, their greater distance from Reds Meadow suggests that if they have a hot-water component, it is probably of even lower temperature.

TABLE 14.—*Temperatures of hot-water components based on mixing calculations and different geothermometers*

	Hot springs	Carbonate springs	
Locality on figure 32	b	c	d
Mixing-model fractions[1]			
Cold fraction (percent)	56	93	95
Hot fraction (percent)	44	7	5
T°C hot fraction (1)	246°	--	--
(2)	191°	232°	--
Silica geothermometer[2]			
T_{SiO2}	152°	794°	84°
T_{Qtz} (adiabatic)	153°	122°	125°
T_{Qtz} (conductive)	162°	125°	127°
Na-K-Ca geothermometer[3]			
$\beta = 1/3$	137°	149°	166°
$\beta = 4/3$	85°	131°	133°

[1]Fournier and Truesdell (1974); (1) assumes heat loss by conduction to conduit walls, (2) assumes heat loss by adiabatic steam separation.
[2]Fournier and Rowe (1966).
[3]Fournier and Truesdell (1973).

HEAT FLOW

During the course of U.S. Geological Survey geothermal investigations of the Long Valley caldera, a hole (DP) for measuring heat flow (Lachenbruch and others, 1976) was drilled to a depth of 250 m near Devils Postpile (fig. 32). This hole, located 1.5 km east of the study-area boundary and 2 km north of Reds Meadow Hot Springs, penetrated 60 m of Pleistocene basalt and continued another 190 m in Cretaceous quartz monzonite of the Sierra Nevada batholith.

The thermal gradient measured in the hole was 51.4°C/km, and the calculated heat flow was 3.75 HFU ($\mu cal \cdot cm^{-2} \cdot s^{-1}$), which is 2.75 HFU higher than the norm for the Sierra Nevada (Lachenbruch and others, 1976, p. 773). Although this represents a substantial thermal anomaly, downward projection of the gradient indicates that a temperature of 100°C would occur only at depths approaching 2 km, and temperatures 160°C would occur only below about 3 km.

The source of this heat-flow anomaly is not identified with certainty. Thermal calculations (Lachenbruch and others, 1976) suggest that conductive heat flow from the Long Valley magma chamber is insufficient to account for the anomaly unless the chamber extends 2 to 3 km beyond the west limit of the caldera. Convection of hot fluids away from the chamber along deep fractures may account for the anomaly, or possibly it is related to the younger basalt-rhyolite volcanism along the Sierra front (Lachenbruch and others, 1976, p. 782). Whatever the heat source, the proximity of drill hole DP to local hydrothermal and magmatic manifestations at Reds Meadow Hot Springs and Mammoth Mountain suggests that the anomaly may be local rather than general in extent. In this context it is noteworthy that heat-flow drill hole JA (Lachenbruch and others, 1976, and fig. 32), 5 km southwest of the study area, has a normal Sierra Nevada heat flow of 1.36 HFU.

GRAVITY AND AEROMAGNETIC STUDIES

Regional gravity and aeromagnetic surveys that include both the study area and the Long Valley geothermal area have been published by Oliver and Robbins (1973) and the U.S. Geological Survey (1974). Interpretation of these surveys relative to the Long Valley geothermal area has been made by Kane, Mabey, and Brace (1976) and by Williams, Berkman, and Mankinen (1977).

On the southeast edge of the study in the vicinity of Devils Postpile, the complete Bouguer gravity map (Oliver and Robbins, 1973; Williams and others, 1977, fig. 5) shows an elongate 10-mGal gravity low, the general configuration of which, although not well controlled, suggests a possible relation to the 40-mGal negative anomaly associated with the Long Valley caldera itself. Approximately coincident with this elongate gravity low is an irregular magnetic low (see anomalies J_1, J_2, pl. 3). Included within the area of these geophysical anomalies are the fumaroles of Mammoth Mountain, the Reds Meadow Hot Springs, and the heat-flow anomaly of Devils Postpile drill hole DP. Examples of the coincidence of gravity and magnetic lows in areas of geothermal potential are well known (Eaton and others, 1975; Isherwood, 1976). However, detailed analysis of the Devils Postpile gravity and aeromagnetic anomalies indicates that they are most likely related to local features that have no particular geothermal significance.

Oliver (Chapter B, this volime) shows that the complex aeromagnetic anomaly J_1-J_2 (pl. 3) is the result of topographic effects produced by the deep canyon of the Middle Fork San Joaquin River. Thus its coincidence with the Devils Postpile gravity anomaly appears to be fortuitous. Its location may be indirectly related to structural or bedrock properties that control the position of the canyon, but it is not related to any rock mass to which the gravity anomaly might also be related.

Superficially, the Devils Postpile gravity anomaly suggests an arcuate feature concentric with the 40-mGal negative anomaly of Long Valley caldera. However, calculations made by D. L. Williams (written commun., 1978) show that the local Bouguer gravity residual, defined by difference from the Long Valley anomaly, is a roughly triangular 8-mGal low, the eastern lobe of which is centered on Mammoth Mountain and the west half of which is elongate generally northwest. The eastern prong, centered on Mammoth Mountain, has closely spaced contours and a half-width of about 1 km, suggestive of a very near surface source—most likely the volcanic edifice of Mammoth Mountain itself, which is composed of relatively low density quartz latite lava and breccia. The western part of the gravity residual has more widely spaced contours and a half-width of about 4 km, suggestive of a somewhat deeper source. The area under this part of the residual is locally veneered by thin basaltic lava that can have little or no gravity expression. The Sierran bedrock beneath is composed of coarsely porphyritic granite of the Cathedral Peak type (Huber and Rinehart, 1965a). This granite has a considerably lower density than most granitic rocks of the Sierra Nevada. The average density of Sierran granitic rocks is generally taken as 2.67 g/cm^3, and all the gravity reductions considered here are based on that figure. In contrast, the densities measured by N. K. Huber on surface samples of porphyritic granite in the Devils Postpile area range from 2.58 to 2.62 g/cm^3, and similar densities were obtained on samples of granite from depths of as much as 250 m in drill hole DP (D. L. Williams, written commun., 1978). The outline of this porphyritic granite pluton closely coincides with that of the western part of the gravity residual and clearly suggests a causative relation. This suggestion is reinforced by the fact that negative gravity anomalies of similar magnitude occur over nearly all other similar young porphyritic plutons along the crest of the Sierra Nevada (H. W. Oliver, oral commun., 1978). Thus the Bouguer gravity residual of the Mammoth Mountain-Devils Postpile area can be satisfactorily accounted for by the combined effects of the low-density mass of Mammoth Mountain itself and the low-density porphyritic granite pluton constituting the basement in the Devils Postpile area. Although the fumaroles of Mammoth Mountain, the Reds Meadow Hot Springs, and the Devils Postpile heat-flow anomaly all occur within the area of these geophysical anomalies, there is little reason to believe that the anomalies are related to or indicative of a hidden geothermal heat source or reservoir.

RESERVOIR ROCKS

The rocks underlying most of the study area are mainly granitic and metamorphic rocks having generally low porosity and permeability. Locally at the surface the metamorphic rocks are intensely jointed and fractured, and the granitic rocks commonly contain large open-joint cracks, but with depth these fractures and joints tend to narrow and become tightly sealed. The fracture porosity below 1 km is probably extremely low. Consequently, even if a significant undiscovered thermal anomaly existed within the study area, the absence of a suitable reservoir rock from which hot fluids could be extracted by drilling would seriously restrict the utilization of any such thermal anomaly.

SUMMARY AND CONCLUSIONS

The general region of the study area has been subjected to three main episodes of volcanism during Cenozoic time: (1) a 3.6- to 2.6-m.y.-B.P. basaltic episode occurring extensively in the high Sierra, (2) a 1.9- to 0.1-m.y.-B.P. rhyolitic episode centered about Long Valley caldera, and (3) a 0.2-m.y. to 725-yr-B.P. basalt-rhyolite episode localized on the east front of the Sierra Nevada. Large shallow silic magma chambers were associated only with the later two episodes; the earlier basaltic episode, though widespread, erupted from centers too small and too dispersed to have significantly affected near-surface heat flow in the study area and is now too old to contribute to the present near-surface thermal regime. Conductive heat flow from the Long Valley magma chamber, though the main cause of thermal activity within the Long Valley caldera itself, was probably insufficient to cause a significant increase in surface heat flow within the study area, 6 km distant from the caldera rim. The Mono Craters magma chamber is too young and probably too deep to affect the present near-surface thermal regime within the study area.

The distribution of fumaroles, hot springs, and cool carbonate springs in and near the study area shows that the intensity of surface hydrothermal activity decreases westward toward the study area. The thermal gradient (51.4°C/km) measured in drill hole DP near Reds Meadow Hot Springs indicates that the hot-water component (<160°C) of the Reds Meadow Hot Springs probably comes from depths greater than 3 km. The low porosity and permeability of the Sierran basement rocks indicate that this hot water must be confined mainly to fractures and joints, which at depth are likely to represent only a small volume of the rock. Thus the volume of deep high-temperature water must be small. Similar reasoning indicates that large reservoirs of lower temperature mixed thermal waters are not likely to occur anywhere in the Sierran basement rocks within the study area.

The approximate coincidence of negative gravity and aeromagnetic anomalies immediately southeast of the study area appears to have no geothermal significance. The aeromagnetic anomaly is the result of topographic effects, and the gravity anomaly is most likely the result of the combined effects of the low-density edifice of Mammoth Mountain and an unusually low density Cretaceous pluton underlying the Devils Postpile area.

On the basis of the available evidence, the Minarets Wilderness and adjacent Roadless areas appear to have little or no geothermal potential.

Economic-Mineral Appraisal of the Minarets Wilderness and Adjacent Areas, Madera and Mono Counties, California

By HORACE K. THURBER, MICHAEL S. MILLER, C. THOMAS HILLMAN, DAVID S. LINDSEY, and RICHARD W. MORRIS,
U.S. BUREAU OF MINES

MINERAL RESOURCES OF THE MINARETS WILDERNESS AND ADJACENT AREAS, MADERA AND MONO COUNTIES, CALIFORNIA

GEOLOGICAL SURVEY BULLETIN 1516-D

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PREVIOUS WORK

Geologic maps covering all of the study area were published by Peck (1980), Huber and Rinehart (1965a), Kistler (1966a), Huber (1968), and Bateman, Lockwood, and Lydon (1971). These maps are the basis for geologic nomenclature, stratigraphy, and structural features. Many of the prospects in the study area were described briefly by Erwin (1934).

Soon after they acquired the Nidever group of claims in 1930, the Treadwell-Yukon Co. cut approximately 30 trenches across the main tactite zones and completed a number of diamond-drill holes. In 1955, the properties were optioned by the then Climax Molybdenum Co., who, in 1956, conducted an exploration program supported by the Defense Minerals Exploration Administation (DMEA). The project included regional and detailed mapping, as well as 3,326 ft (1,014 m) of diamond core drilling.

In 1945, the U.S. Bureau of Mines conducted a diamond core drilling program on the Minarets magnetite deposit. The exploration work was done under the Strategic Minerals Program, and the results were presented in Report of Investigations 3985 (Severy, 1946). A detailed magnetometer survey was conducted by a private exploration company in 1962 (see Chapter B, this volume) and by the U.S. Bureau of Mines during the present study. Several California Division of Mines reports discussed the Minarets iron deposit (Watts, 1893, p. 214; Trask and Simons, 1948); Trask and Simons described the geology and mineralogy in detail and included an ore-reserve estimate.

PRESENT INVESTIGATIONS

The U.S. Bureau of Mines' field investigations of the Minarets Wilderness study area were conducted in 1975 and 1976. Investigations were made by all five authors, assisted by Timothy S. Percival, Dennis R. Kerr, Dale T. Reitz, June B. Worthington, and Douglas D. Harby. Approximately 780 man-days were devoted to field investigations, during which all known mineral occurrences in the study area were examined. Mining-claim data were obtained from the courthouse records of Fresno, Madera, Mono, and Inyo Counties. Information was taken from published and unpublished reports by the California Division of Mines and Geology, U.S. Bureau of Mines, U.S. Geological Survey, and private mining companies. Production records were compiled from U.S. Bureau of Mines statistical files.

METHODS OF STUDY

County, State, Federal, and private records and reports were used to determine the locations of prospects and claims. Owners were contacted to obtain permission to examine their properties. All lode prospects were examined and sampled, and most lode prospects were mapped.

Of 864 lode samples taken, there were four types: chip, a series of continuous rock chips across or along a mineralized structure; random chip, a collection of rock chips from an exposure; grab, an unselected assortment of rock pieces from a rock pile or exposure; and select, handpicked material of the highest grade rock available.

A total of 73 placer samples were taken by shovel at favorable localities, usually along major drainage channels. These samples were reduced by hand panning. None contained gold or other precious metals.

All lode samples were crushed, pulverized, mixed, and split, and then were checked for the presence of radioactive and fluorescent minerals. Lode samples also were fire assayed to determine gold and silver concentrations. The presence of other metallic constituents was determined by atomic-absorption, colorimetric, or X-ray fluorescence methods. At least one sample from each mineralized structure was analyzed by semiquantitative spectrographic methods. If anomalous amounts of any economic elements were detected, more accurate analyses were made. Spectrographic analyses are not listed with the sample data (tables 15–28).

Lode resource estimates were calculated by multiplying the thickness of the mineralized structure by its measured or inferred length. The product was then multiplied by the depth, and this product was divided by the approximate number of cubic feet of material per ton. In most cases, the depth could not be measured, and so it was estimated as one-half the length.

RESOURCE DEFINITIONS

Resources have been classified according to the following definitions (U.S. Bureau of Mines and U.S. Geological Survey, 1976):

Resource—a concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust in such form that economic extraction of a commodity is currently or potentially feasible.

Reserve—that portion of the identified resource from which a usable mineral and energy commodity can be economically and legally extracted at the time of determination. The term "ore" is used for reserves of some minerals.

Indicated—reserves or resources for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to permit the mineral bodies to be outlined completely or the grade established throughout.

Inferred—reserves or resources for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition, of which there is geologic evidence; this evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geologic evidence of their presence. Estimates of inferred reserves or resources should include a statement of the specific limits within which the inferred material may lie.

Paramarginal—the portion of subeconomic resources that (1) borders on being economically producible or (2) is not commercially available solely because of legal or political circumstances.

Submarginal—the portion of Subeconomic Resources that would require a substantially higher price (more than 1.5 times the price at the time of determination) or a major cost-reducing advance in technology.

Acknowledgments.—Personnel of the North Fork Ranger Station assisted U.S. Bureau of Mines crews in the fieldwork on Sierra National Forest by providing communications and other services.

SETTING

Historical records tell of at least three poorly defined mining districts within the Minarets study area: the old Minarets mining district, in the east-central part of the area, including most of the important groups of claims and mineralized areas within the present study area; and the Tioga and Prescott mining districts in the northern part.

No production has been recorded from any of the claims within the study area; however, bulk samples for metallurgic testing have been taken from the Minarets magnetite deposit, the Nydiver Lakes area, and the Mark prospect (fig. 33). Between 1878 and 1881, the Mammoth mine and others in the vicinity produced gold valued at more than \$200,000, at a price of \$20.67 per troy ounce (34.3 g), and eventually the Mammoth district may have produced as much as \$1 million worth of gold, silver, and other metals (Rinehart and Ross, 1964, p. 98). This production stimulated prospecting in nearby parts of the study area. The Strawberry mine produced more than 40,000 short ton units or hundredweight (800,000 lb [360,000 kg]) of tungsten trioxide (WO_3) up to 1953 (U.S Bureau of Mines files). Later production by various lessees has not been recorded.

Mineral deposits in the study area are in intrusive rocks, metavolcanic rocks, hornfels, or carbonaceous marble intruded by granitic rocks. The most important event governing mineral emplacement was the intrusion of plutons of Triassic through Cretaceous age into the older metasedimentary and metavolcanic rocks of the Ritter Range pendant. In some areas, the metallic minerals are associated with contact metamorphism. In others, hydrothermal solutions introduced quartz and metallic minerals along joints, fractures, and bedding planes in the metamorphic rocks. In the Lake Catherine area (fig. 33, No. 5), sulfide minerals are deposited in a major vertical fracture in an andesite dike. On the Iron Mountain prospect (fig. 33, No. 12), the main magnetite body is an elongate lens in a sequence of slightly metamorphosed basaltic to andesitic rocks. The deposition of copper-bearing minerals in bedded glassy tuff makes the Mark mine (fig. 33, No. 15) unique in the study area. The copper minerals occur in gash veins and lenticular masses along shears and joints, as well as in disseminations along contorted bedding planes.

Because of indefinite boundary description and sometimes-ambiguous names of mining districts, the area divisions used in this report are based on groups of claims and workings, or known mineralized areas. Figure 33, an outline map of the study area, shows the location of the major prospects and mineralized areas discussed.

Submarginal resources of silver, copper, lead, and zinc occur in the Nydiver Lakes, Alger Lakes, and Mono Pass areas (fig. 33, Nos. 3, 7, and 1), and of iron at the Mono Pass and Iron Mountain prospects (fig. 33, Nos. 1 and 12). A small paramarginal resource of copper and silver exists at the Mark prospect (fig. 33, No. 15). Rocks

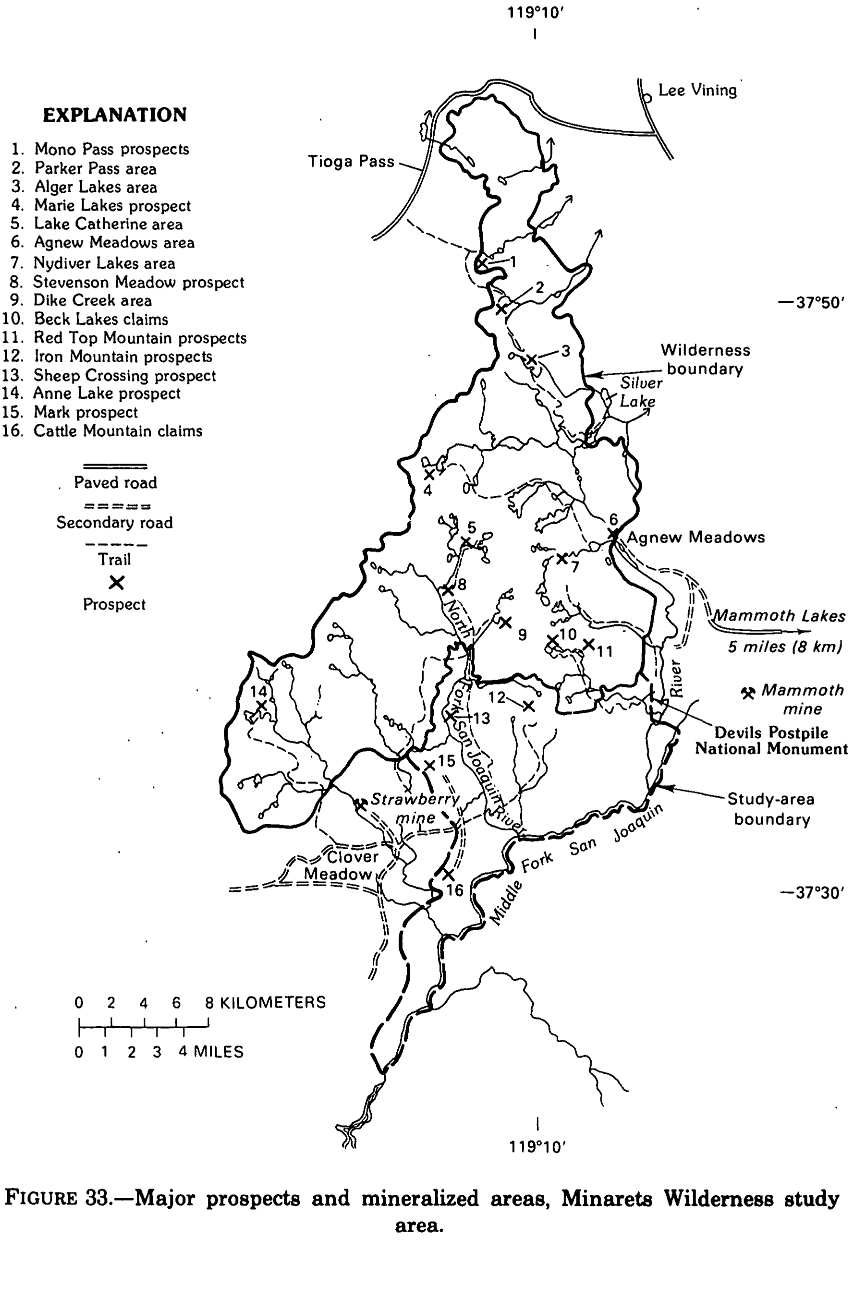


FIGURE 33.—Major prospects and mineralized areas, Minarets Wilderness study area.

with low-grade mineralization representing minor amounts of contained metal occur on most other prospects.

A search of county records indicates that since the 1870's, more than 1,200 mining claims have been located in the study area. Probably fewer than 25 claims were actively held at the time of this investigation. Nine claims are patented; two are on the Iron Mountain magnetite deposit, three are on Mono Pass, and four are near the north fork of Iron Creek. Several placer claims were located on the Middle Fork San Joaquin River, the North Fork San Joaquin River, and Granite Creek, but records show that none are current.

STUDY-AREA DIVISIONS

NYDIVER LAKES AREA

The Nydiver Lakes area (fig. 33, No. 7; fig. 34) is near the midpoint of the study area. Access is by trail from Agnew Meadows. One route is along Shadow Creek to the Crown Point-Nidever prospect; another follows Minaret Creek to the Minarets prospect.

The terrain is rugged, with glacial cirques and steep-walled canyons. Elevations range from 9,200 ft (2,800 m) beside Shadow Creek to 11,200 ft (3,414 m) on Volcanic Ridge. All streams are tributary to the Middle Fork San Joaquin River. In the lower stream valleys, vegetation is abundant. Stunted conifers and low bushes partly cover the main prospect areas.

In 1901, the first claims were staked on tactite outcrops near Nydiver Lakes, Shortly after, prospecting revealed metallic-mineral deposits south of Shadow Creek and led to the staking of more than 100 claims between 1901 and 1972. The Crown Point-Nidever prospect was explored by trenching and diamond core drilling in 1930–31 and again in 1956.

From a point south of the Minarets prospect to the ridge between Nydiver Lakes and Garnet Lake, a distance of about 3 mi (5 km), tactite bodies containing zinc, lead, and copper sulfides occur in several contorted metamorphosed limestone beds that strike N. 25°–35° W. Steeply dipping northwest-striking faults offset the beds in echelon to the northwest. Minor faults are evident near the mine workings. The mineralized zones are as much as 70 ft (21 m) wide.

The Crown Point-Nidever prospect has about 9.1 million tons (8.3 million t) of submarginal resources. Drilling data and surface sampling indicate a grade of as much as 0.5 troy oz of silver per ton (17 g/t), 0.4 percent copper, 0.2 percent lead, and 1.9 percent zinc. Selective mining of high-grade areas within the deposit would raise

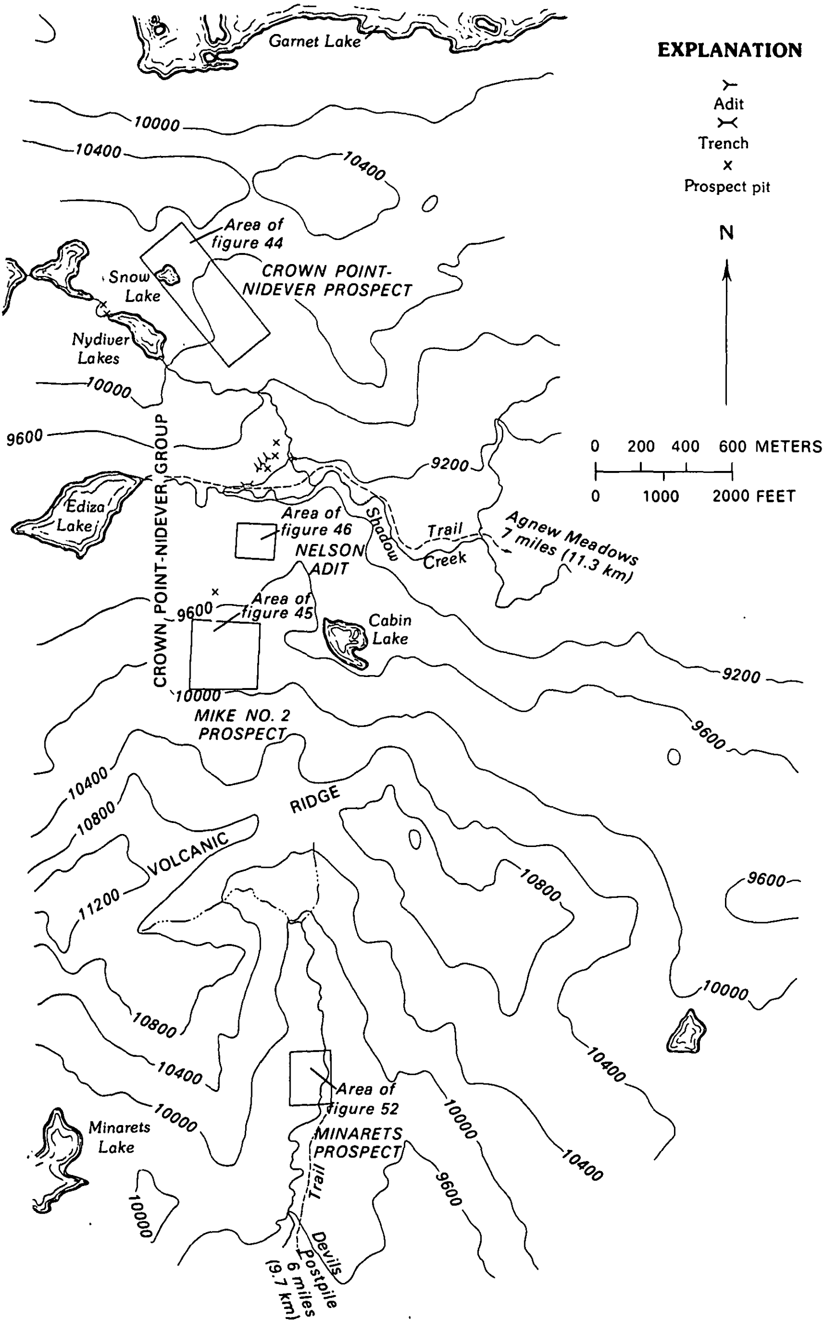


FIGURE 34.—Prospects in the Nydiver Lakes area. See Figure 33 for location. Contours in feet.

the average grade of metallic minerals substantially, but decrease the tonnage.

ALGER LAKES AREA

The Alger Lakes area is in the north-central part of the study area (fig. 33, No. 3; fig. 35). Access is by 7 mi (11 km) of trail from Silver Lake. The area is in a hanging glacial valley, oriented northwest-southeast. The southwest wall is precipitous, the northeast more gradual. Alpine and subalpine flora predominate at elevations of about 10,000 ft (3,000 m).

Seven lode claims were staked in the Alger Lakes area between December 1882 and October 1911. Workings include one open adit, three partly caved adits, two shafts, and nine pits and trenches. There has been no recorded production from the claims, and there is no current prospecting activity.

Metallic minerals are in Permian felsitic tuff and Pennsylvanian quartzofeldspathic hornfels, calc-silicate hornfels, and quartzite. Pyrite, chalcopyrite, galena, and wolframite were probably introduced by hydrothermal solutions from underlying Mesozoic intrusions. The metallic minerals occur along fractures, joints, and fault planes that generally trend northwest.

The Independence claim has about 685 tons (621 t) of indicated and inferred submarginal resources. This resource may average in grade as much as 1.5 troy oz of silver per ton (51 g/t), 0.25 percent lead, and 1.7 percent WO_3.

The small, submarginal resource, combined with transportation difficulties and severe weather conditions, makes further mining development in the Alger Lakes area unlikely.

AGNEW MEADOWS AREA

The Agnew Meadows area (fig. 33, No. 6; fig. 36) extends northwest from Agnew Meadows for approximately 3 mi (5 km). It straddles the east border of the study area, and mineralization extends across the study-area boundary. Access is by road from Mammoth Lakes.

Elevations range from 8,000 ft (2,400 m) to 10,800 ft (3,290 m), with moderate to steep terrain. Slopes are tree- and brush-covered, with dense stands of coniferous trees in many sections. The terrain, soil, and talus cover are amenable to road construction.

In 1878, Tom Agnew staked the first claims. Eventually, there were 42 in the area. There is no recorded production, and there are no patented claims or claims currently held.

Discontinuous quartz veins occur as fracture fillings in a northwest-trending sequence of hornfels and dark graphitic phyllite. Pyrite, galena, sphalerite, and argentite(?) are confined to narrow

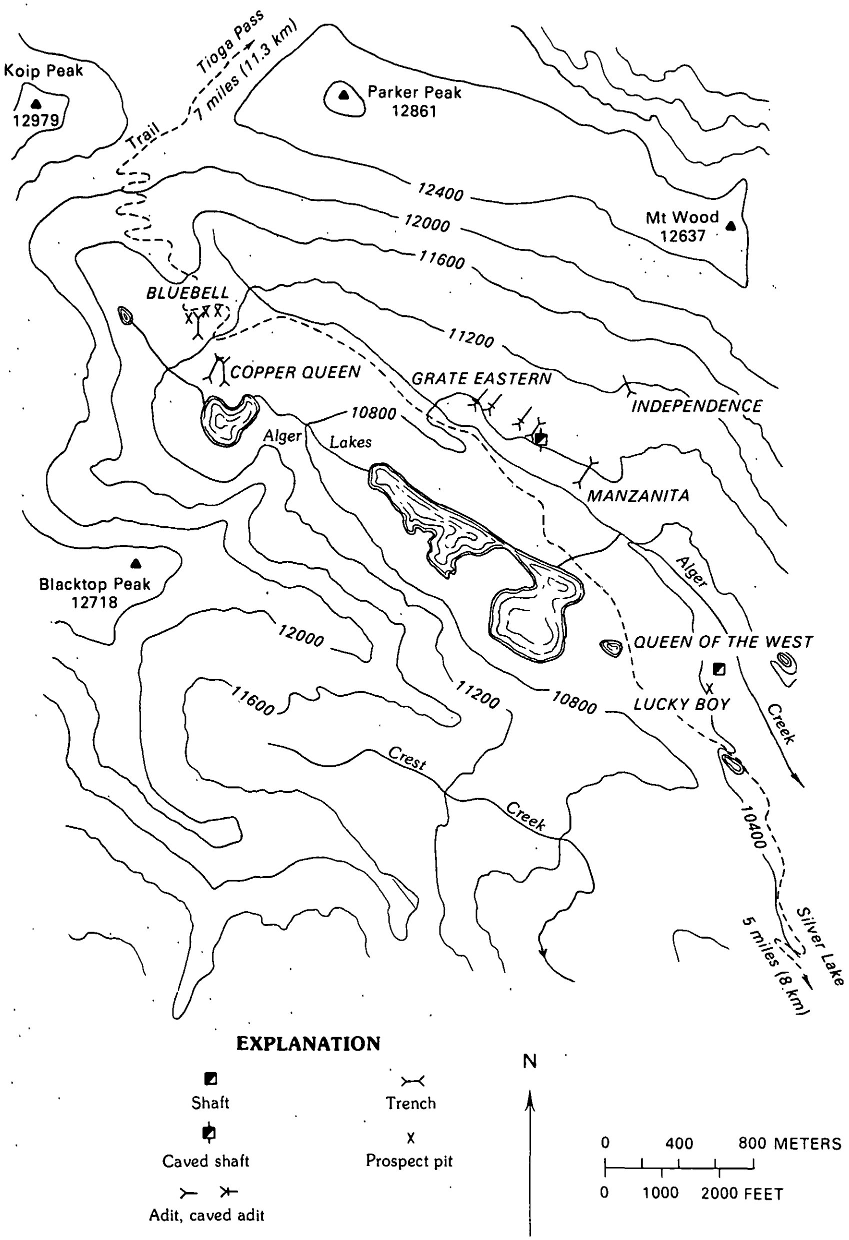


FIGURE 35.—Prospects in the Alger Lakes area. See figure 33 for location. Contours in feet.

quartz veins that occur in east-west-trending fractures.

In all workings and mineralized exposures, the sulfide minerals were deposited erratically over small areas. This erratic pattern of mineralization suggests that the area has little mineral-resource potential.

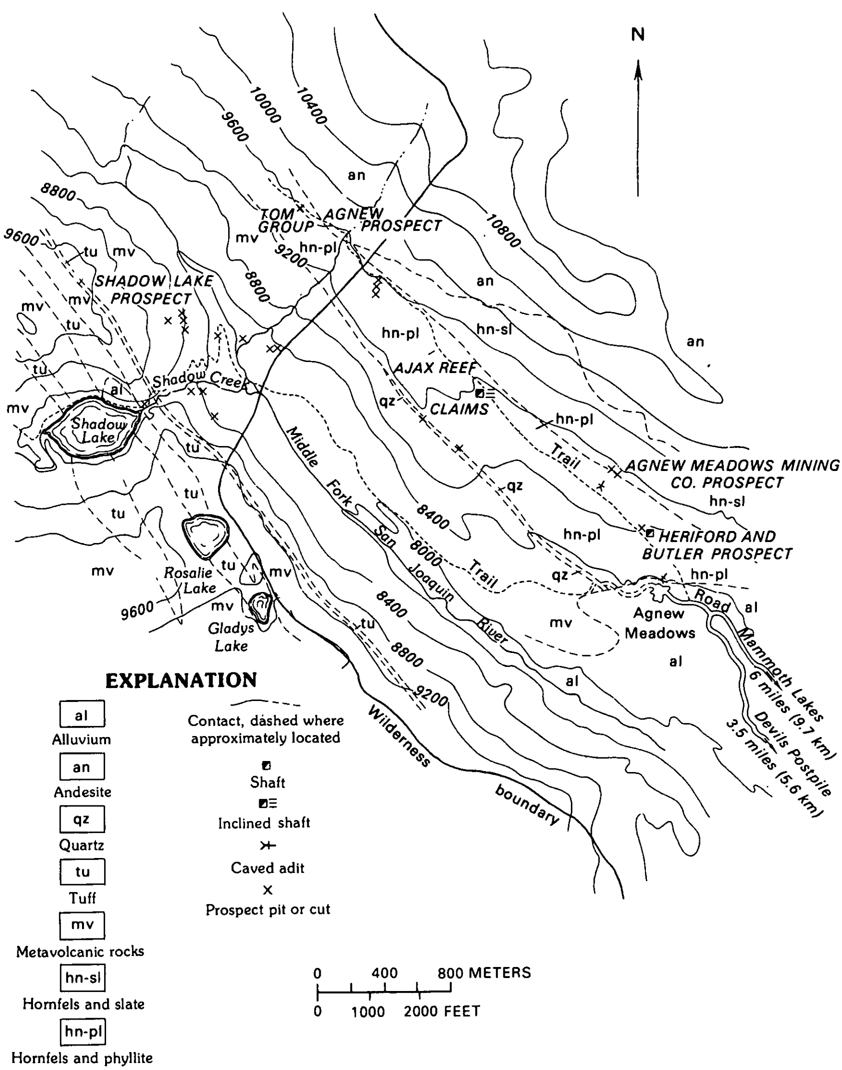


FIGURE 36.—Prospects in the Agnew Meadows area. Geology after Huber and Rinehart (1965a). Quartz (qz) in explanation should read "quartz-andalusite-corundum-bearing rock." See figure 33 for location. Contours in feet.

LAKE CATHERINE AREA

Several prospects containing minor sulfide mineral occurrences are in the Lake Catherine area near the west boundary of the study area (fig. 33, No. 5). Access is by steep trails from the road at Clover Meadow, by way of Stevenson Meadow and the North Fork San Joaquin River (fig. 37). The area's relief is about 3,200 ft (975 m), and the terrain steep.

The Bliss prospect, apparently one of the area's early workings, was operated in the late 1800's and early 1900's. Other claims were staked in 1926 and relocated several times until the 1950's. The Pat No. 1 claim (fig. 37) was relocated August 27, 1957. Production is reported from one claim, the Galena King, but no workings fitting

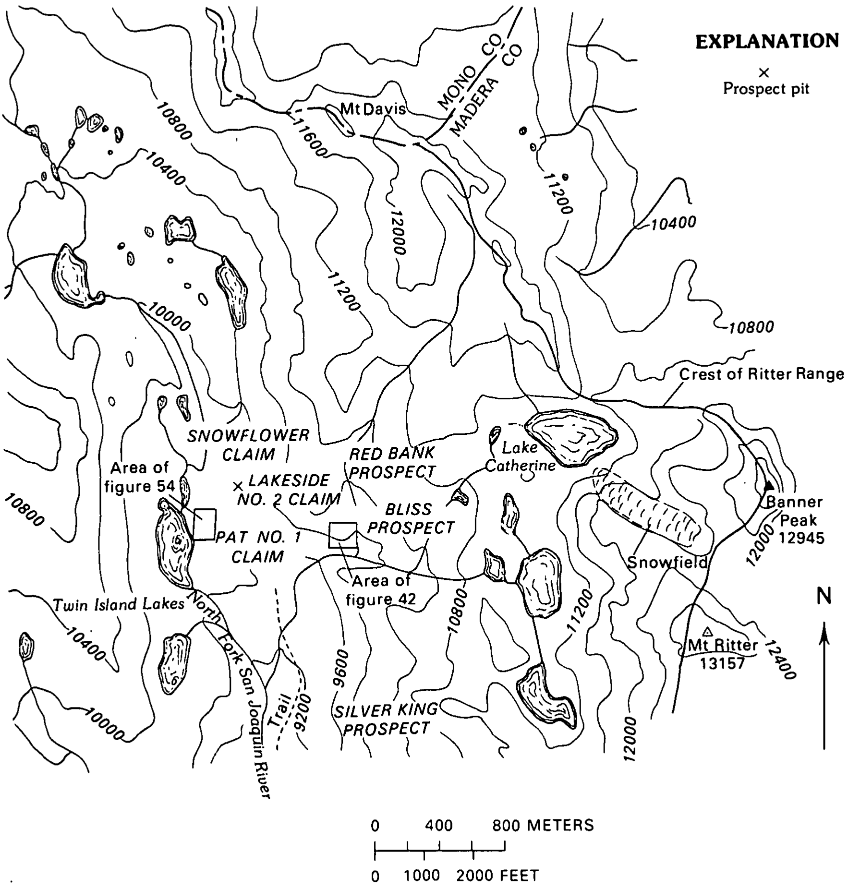


FIGURE 37.—Prospects in the Lake Catherine area. See figure 33 for location. Contours in feet.

the description of this property could be found in a wide reconnaissance of the area. Presently, there are no exploration or mining activities on the prospects in the Lake Catherine area.

All prospects but one are along shear zones filled with quartz, metallic sulfides, sericite, and secondary minerals. The one exception is a sheer zone partly filled with quartz and an andesite dike rock. The main structural features are north-south- and northwest-trending faults, sinuous in places, dipping 30°-50° west and southwest.

In the northern part of the Lake Catherine area, intensely altered shear zones contain galena and minor amounts of sphalerite in stringers and blebs. Copper content, however, is low. The discontinuity and generally small sizes of structures containing the metallic minerals preclude any estimation of resources.

PARKER PASS AREA

The Parker Pass area is in the northern part of the study area, near the west boundary (fig. 33, No. 2). Access is by trail from the Tioga Pass road in Yosemite National Park. The terrain consists of moderate to steep rock slopes. The prospects are between the 9,600-ft (2,930 m) and 12,400-ft (3,780 m) elevations.

In the main, the scattered workings of Parker Pass (fig. 38) are in the major band of hornfels and carbonaceous marble. A few minor workings are in the felsitic tuff north of Koip Peak. The area's major structures are two subparallel faults striking N. 30°-35° W. (pl. 1).

Apparently, the first Parker Pass area prospecting was during the late 1870's and 1880's, following activity in the nearby Mono Pass area. There is no recorded production or current activity.

DIKE CREEK AREA

The Dike Creek area is approximately midway between the east and west boundaries of the Wilderness, near the south boundary (fig. 33, No. 9). Access is by trail from Clover Meadow by way of the North Fork San Joaquin River, then up Dike Creek or the north fork of Iron Creek (fig. 39). The slopes are moderate to steep and covered by alpine vegetation.

Claims were located in the area before 1914; however, no production was recorded. The Vera Mae and Big Lead-Eagle claims were surveyed for patent in 1916, and patents were issued later. Workings on the Vera Mae and Big Lead-Eagle are so small that no significant production could have resulted from their excavation. No current activity is evident in the area.

Quartz veins occur mainly in quartz monzonite of the Shellenbarger Lake pluton. This small pluton is surrounded by meta-andesite, metabasalt, and other, undifferentiated metavolcanic rocks. Prominent quartz veins are found along northwest-trending shear zones that dip 30°-80° NE. Numerous smaller structures with quartz veins are in east-west-trending vertical shear zones.

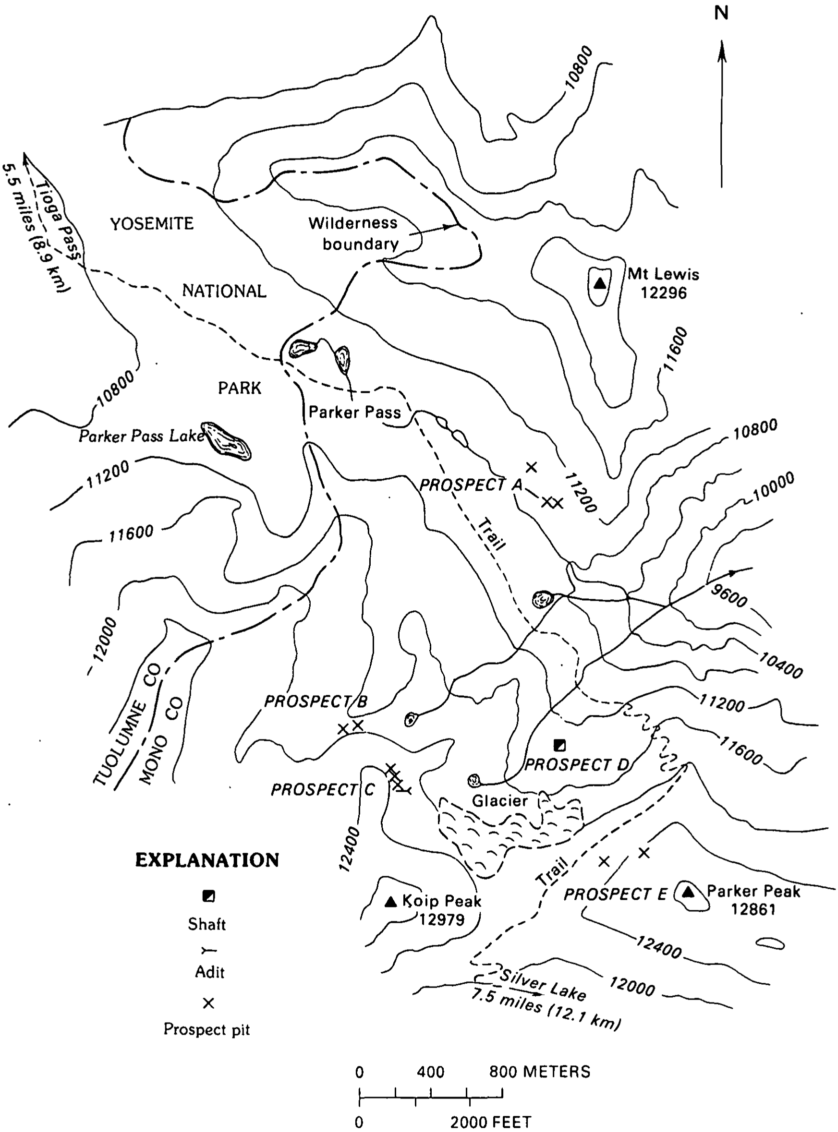


FIGURE 38.—Prospects in the Parker Pass area. See figure 33 for location. Contours in feet.

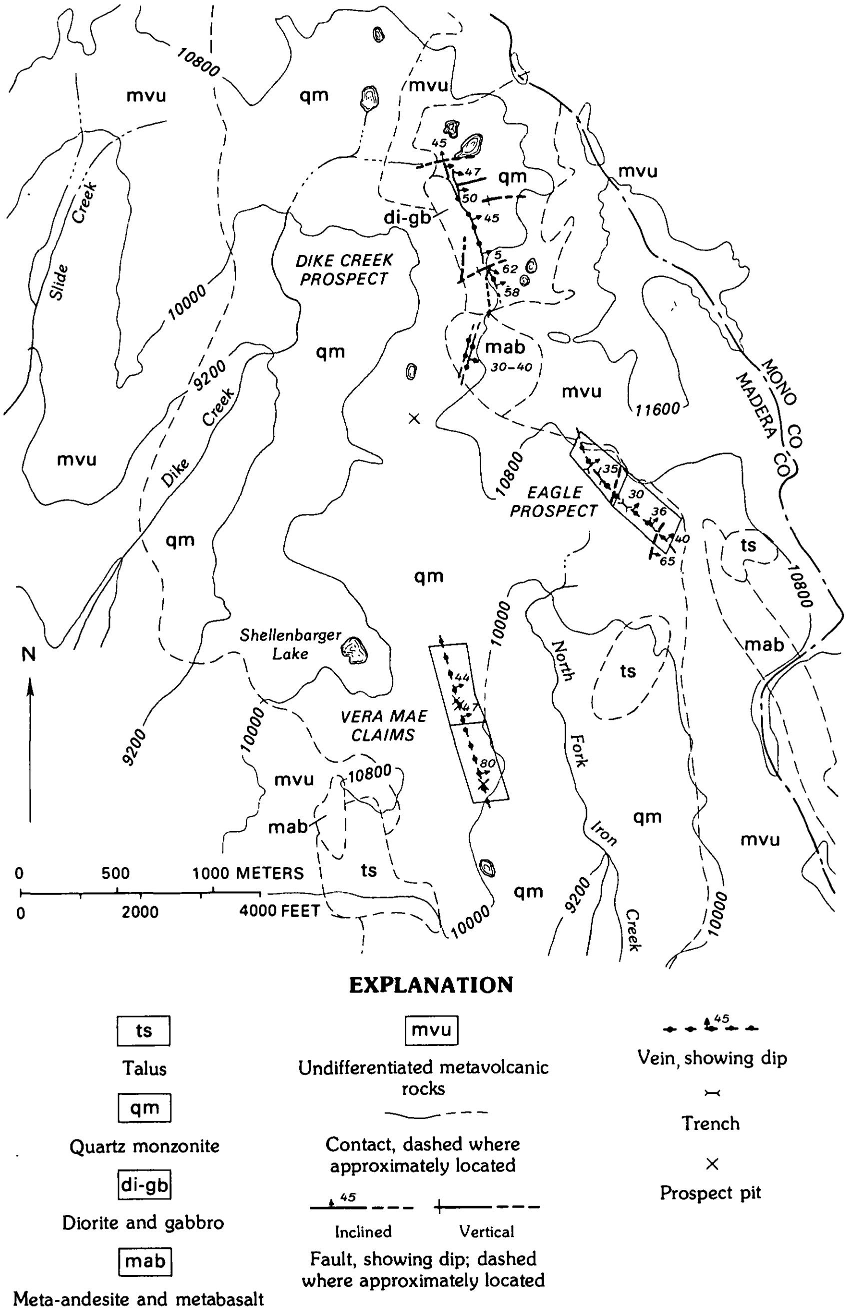


FIGURE 39.—Prospects in the Dike Creek area. Geology after Huber and Rinehart (1965a). See figure 33 for location. Contours in feet.

Metallic minerals in the Dike Creek quartz veins are pyrite, wolframite, and chalcopyrite. Scheelite occurs in the wolframite. The wolframite, in turn, occurs in isolated widely scattered blebs and very short stringers, seldom more than 0.5 ft (15 cm) long, within the quartz veins. Lesser amounts of chalcopyrite are near the blebs of wolframite.

Low sample values and the very localized metallic minerals on the claims preclude a resource estimate.

OUTLYING CLAIMS AND PROSPECTS

Scattered claims and prospects in the study area, but not in the geographic divisions previously described, are briefly discussed below.

IRON MOUNTAIN PROSPECTS

The Iron Mountain prospects (fig. 33, No. 12) are characterized by steep terrain covered by sparse alpine vegetation. Access is by trail from Clover Meadow (fig. 40).

The Magnetic Iron and Bull of the Woods Iron claims, which cover the Minarets magnetite deposit, were located in 1883 and patented in 1914. Magnetometer surveys and surface samplings were conducted more recently. No production has been recorded from the deposit, and there is no current activity in the area.

Metavolcanic and metasedimentary rocks, and minor mafic or ultramafic and granitic rocks, crop out in the Iron Mountain area (fig. 40), which is transected by felsic and mafic dikes and quartz veins. Most magnetite lenses are subparallel to northwest-trending structures.

The Minarets magnetite deposit contains an estimated 8.5 million tons (7.7 million t) of indicated and inferred submarginal resources. The average grade is more than 27 percent iron. Numerous smaller magnetite deposits also exist in the Iron Mountain area.

Because of low grades, small sizes, and inaccessibility, it is unlikely that any of these deposits will be mined in the near future.

MARK PROSPECT

The Mark prospect (fig. 33, No. 15) is on the west side of the North Fork San Joaquin River. A privately maintained road extends 2.5 mi (4.0 km) from a Forest Service road to the mine workings near the study-area boundary. Relief at the workings is about 250 ft (76 m). Vegetation is sparse.

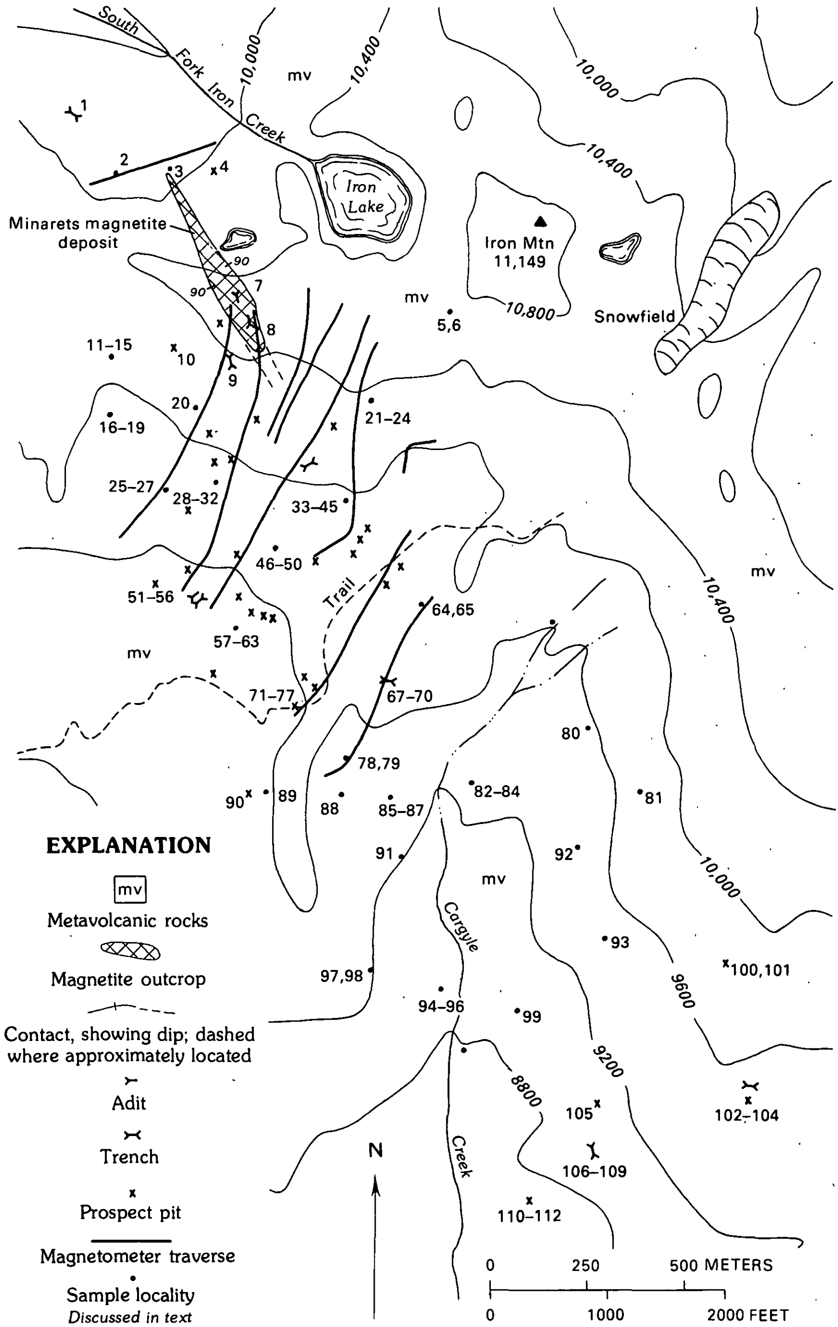


FIGURE 40.—Iron Mountain prospects. See figure 33 for location. Contours in feet.

Claims, which include the Mark prospect, were located in the 1950's by Denton Wolfe. Exploration work and development have been sporadically conducted by him, and small lots of vein material have been shipped for mill testing.

Quartzose metamorphic rocks, sedimentary rocks, and tuff that have been contorted by multiple folding and faulting crop out on the prospect. Intrusive granitic rocks (the Mount Givens Granodiorite) lie less than 400 ft (120 m) in elevation below the outcrops. Predominantly north-south to northwest trending shear zones, gash vein zones, breccia zones, and joints are the most important mineralized structures. They contain chalcocite, bornite, pyrite, covellite, chalcopyrite, and tetrahedrite. Azurite, malachite, and chrysocolla coat the weathered, sulfide-rich parts of the structures.

At least 30,000 tons (27,000 t) of paramarginal resources averaging 1.9 troy oz of silver per ton (65 g/t) and 1.08 percent copper are on the Mark prospect. Drilling would not only more clearly determine the grade, but might indicate additional resources.

MONO PASS PROSPECTS

The Mono Pass prospects are at the north end of the study area (fig. 33, No. 1). A trail from the Tioga Pass Highway leads to the claims, which are on gently sloping terrain. Elevations are above 10,000 ft (3,000 m), at which only small conifers and low brush grow. The Ella Bloss, Ella Bloss No. 2, and Golden Crown Quartz Mine claims were located in the summer of 1879. They were surveyed for patent in 1884, and patents were issued later. There has been no recorded production from the Mono Pass group of claims, and there is no present activity.

On the claims, hornfels is separated from volcanic tuff by a steeply dipping northwest-striking fault. Pyrite, marcasite, and arsenopyrite are found in the fault and subparallel structures, and are most abundant on the Golden Crown claim.

Approximately 5,000 tons (4,500 t) of submarginal resources exist on the Golden Crown claim, averaging 5.02 troy oz of silver per ton (172 g/t) and 0.08 troy oz of gold per ton (2.7 g/t).

RED TOP MOUNTAIN CLAIMS

The Red Top Mountain claims are near the study-area boundary (fig. 33, No. 11), northeast of 10,532-ft (3,210 m) Red Top Mountain. The claims are reached by trail from the road head at Devils Postpile National Monument. The terrain is moderate to steep, and slopes are covered by alpine vegetation.

Records show that 38 claims were staked in the Red Top Mountain area between 1879 and 1935. None were patented, and there is no recorded production.

Country rock is the Upper Cretaceous granodiorite of Lost Dog Lake. Numerous shear zones, joints, fractures, and aplite dikes are believed to have formed with the emplacement of a younger quartz monzonite (Chapter A, this volume). Minor concentrations of silver, copper, molybdenum, and tungsten minerals are associated with these structures.

No resource estimates could be made for the claims. However, sample analyses of weathered surface material indicate the possibility of higher grade molybdenum mineralization at depth.

ANNE LAKE PROSPECT

The Anne Lake prospect (fig. 33, No. 14) is reached by trail from Clover Meadow. Two small tactite pods in granitic rocks underlie the prospect. The pods and dumps have about 200 tons (180 t) of tactite containing 20 to 80 short ton units (400–1,600 lb [180–725 kg]) of WO_3.

CATTLE MOUNTAIN CLAIMS

The Cattle Mountain claims (fig. 33, No. 16) are in coarsely crystalline granitic rocks containing pegmatitic zones. Pyrite occurs locally, but no apparent mineral resources exist.

BECK LAKES CLAIMS

The Beck Lakes claims (fig. 33, No. 10) are underlain by granodiorite and metavolcanic rocks. Highly iron oxide stained rhyolite dikes containing finely disseminated pyrite are found mainly in the granodiorite. These dikes have low metallic contents, and no mineral resource is indicated.

MARIE LAKES PROSPECT

The Marie Lakes prospect is southeast of Mount Lyell (fig. 33, No. 4). Quartz monzonite and andesite containing felsic and pegmatitic dikes crop out on the prospect. Sample analyses showed no gold or silver and only small amounts of copper, lead, and zinc.

SHEEP CROSSING PROSPECT

The Sheep Crossing prospect (fig. 33, No. 13) is underlain by pegmatite lenses in granodiorite. Sample analyses indicate no mineral-resource potential.

STEVENSON MEADOW PROSPECT

The Stevenson Meadow prospect is along the North Fork San Joaquin River (fig. 33, No. 8). A pod of pyrophyllitic rock occurs near a metavolcanic-intrusive rock contact. Widely scattered quartz veins with sulfide mineralization also crop out on the prospect. Sample analyses indicate no mineral-resource potential.

LODE PROSPECTS AND CLAIMS

Prospects and claims examined in the study area are described on the following pages in alphabetical order. Indicated ownerships are as of 1975.

NAME: Agnew Meadows Mining Co. prospect
INDEX MAP NO.: Fig. 33, No. 6; fig. 36
LOCATION: Northwest of Agnew Meadows
ELEVATION: 9,100 ft (2,800 m)
ACCESS: By trail 1 mi (1.6 km) north from Agnew Meadows
GEOLOGY OF DEPOSIT: Hornfels and dark-gray phyllite have quartz veins as much as 1 ft (0.3 m) thick and quartz pods from 2 to 5 ft (0.6–1.5 m) thick. Both the veins and pods trend nearly east-west, and most contain disseminated pyrite and galena.
DEVELOPMENT: One 14-ft (4.3 m)-deep inclined shaft, one caved adit, and two open pits
SAMPLING: Four chip and two select samples of quartz vein material were taken. A select sample from the inclined-shaft dump assayed 0.12 troy oz of gold per ton (4.1 g/t), 6.8 troy oz of silver per ton (230 g/t), and 0.56 percent lead. Other samples had erratic metal contents, with as much as 0.16 troy oz of gold per ton (5.5 g/t), 1.4 troy oz of silver per ton (48 g/t), 0.94 percent lead, and 0.3 percent copper.
CONCLUSIONS: Additional subsurface work might disclose minor resources.

NAME: Ajax Reef claims
INDEX MAP NO.: Fig. 36
LOCATION: Approximately 6,000 ft (1,830 m) northwest of Agnew Meadows, just outside the Wilderness boundary
ELEVATION: 9,100 ft (2,800 m)
ACCESS: By trail 1.5 mi (2.4 km) northwest from Agnew Meadows

HISTORY: Two claims were staked by P. J. Barnes in 1944.

GEOLOGY OF DEPOSIT: Claims are on a prominent elongate outcrop composed of quartz and andalusite with lesser amounts of muscovite, corundum, and pyrite. Quartz veins as much as 1 ft (0.3 m) wide transect the northern part of the outcrop. Pyrite occurs locally in blebs and is typically oxidized on the surface.

DEVELOPMENT: Two prospect cuts

SAMPLING: Four samples were from the prospect cuts and one from across a pyrite-bearing quartz vein. Samples contained as much as 0.3 troy oz of silver per ton (10 g/t), 0.02 percent copper, and 0.02 percent lead.

CONCLUSIONS: No metallic resources are apparent. Two petrographic thin sections show corundum and andalusite in the rock mass of the outcrop, but not in economically significant concentrations.

NAME: Anne Lake prospect

OWNER: Mr. Guy Richardson, Fresno, California

INDEX MAP NO.: Fig. 33, No. 14

LOCATION: About 0.25 mi (0.40 km) north of Anne Lake

ELEVATION: 9,530 ft (2,905 m)

ACCESS: By trail 7 mi (11 km) northwest from Clover Meadow

GEOLOGY OF DEPOSIT: Two tactite pods are near the contact of xenolithic and iron-oxide-stained granitic rocks. The pods trend north, dip 30°-45° E., and are about 60 ft (18 m) long and as much as 15 ft (4.6 m) thick. Predominant minerals in the tactite are garnet, amphibole (some asbestiform), quartz, pyroxene, epidote, magnetite, and scheelite.

DEVELOPMENT: A 60-ft (18 m)-long trench containing two pits and a water-filled shaft

SAMPLING: Five samples were taken (fig. 41). Analyses are listed in table 15. The samples contained as much as 0.22 percent zinc, 0.42 percent WO_3, and trace amounts of silver and copper.

RESOURCE ESTIMATE: At least 200 tons (181 t) of tactite con-

TABLE 15.—*Analytical data for Anne Lake prospect*

[Sample locations shown on figure 41. Tr, trace; N, none detected; <, less than shown]

Sample				Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Zinc (percent)	Tungsten trioxide (WO_3) (percent)
No.	Type	Length (feet)[1]	Description				
1	Chip	2.0	Across garnet-bearing tactite	N	N	0.13	0.12
2	Grab	--	Stockpile of tactite	N	N	.22	.42
3	Chip	8.0	Across garnet-bearing tactite	N	Tr	.019	.04
4	Grab	--	Tactite on dump	N	N	.084	.09
5	Chip	45.0	Across altered granitic rock	N	N	.01	<.03

[1]Metric conversions: feet × 0.3048 = meters; troy ounces per ton × 34.285 = grams per tonne.

taining 20 to 80 short ton units (400-1,600 lb [180-725 kg]) of WO_3 are in the pods and on dumps.

CONCLUSIONS: The grade is too low and the submarginal resources too small to justify mining under 1979 market conditions.

NAME: Beck Lakes claims
INDEX MAP NO.: Fig. 33, No. 10
LOCATION: On the saddle south of Beck Lakes
ELEVATION: Approximately 10,600 ft (3,230 m)
ACCESS: By trail 7 mi (11.3 km) west from Devils Postpile National Monument
HISTORY: C. J. Beck located claims in the Beck Lakes area. Some were surveyed for patent and vigorously promoted around the turn of the 20th century.

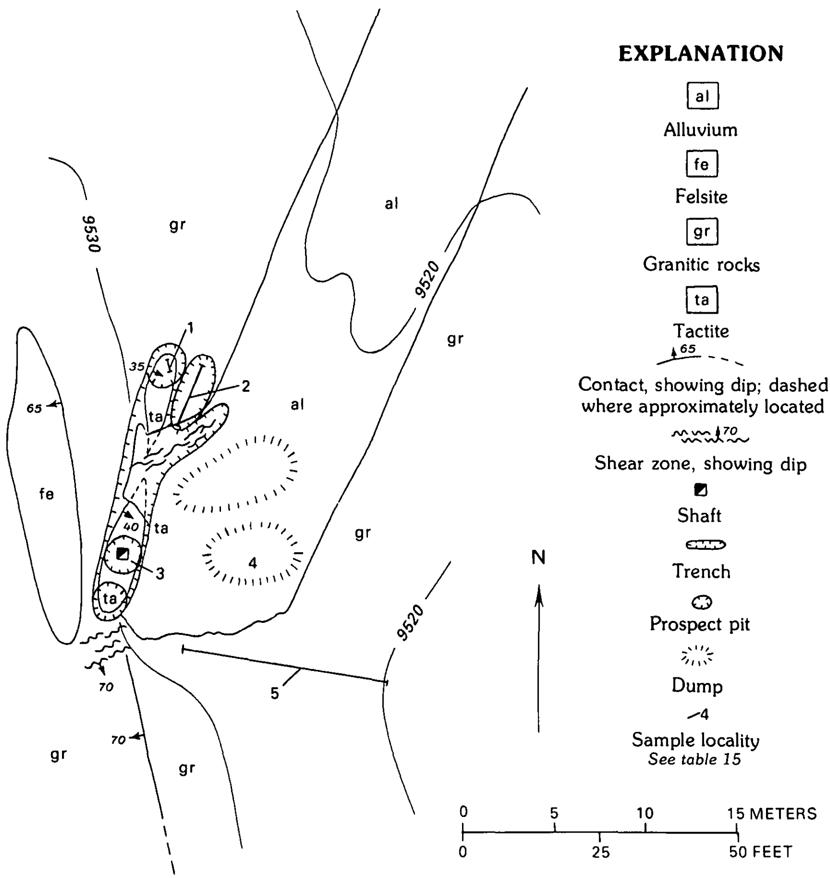


FIGURE 41.—Anne Lake prospect. See figure 33 for location. Contours in feet.

GEOLOGY OF DEPOSIT: The claims are along the contact between granodiorite and metavolcanic rocks. Rhyolite and unmineralized mafic dikes occur in the area, mainly in the granodiorite, but some penetrate the metavolcanic rocks. Highly iron oxide stained, gossanlike zones are mainly in rhyolite dikes. These zones have maximum lengths of 30 ft (9.1 m) and are 2 to 6 ft (0.6–1.8 m) thick.
DEVELOPMENT: One prospect pit
SAMPLING: Three chip samples of highly iron oxide stained material had no significant metallic content.
CONCLUSIONS: The claims have no evident mineral-resource potential.

NAME: Bliss prospect
INDEX MAP NO.: Fig. 37
LOCATION: Approximately 1 mi (1.6 km) west of Lake Catherine
ELEVATION: 10,100 ft (3,080 m)
ACCESS: By trail 15 mi (24 km) northeast from Clover Meadow
HISTORY: Work was done in the late 1800's and early 1900's.
GEOLOGY OF DEPOSIT: Gray to black metavolcanic rocks, granitic rocks, basaltic dikes, and limestone crop out in the area. The metavolcanic rocks are hornfelsed and porphyritic, with relict angular fragments. The main mineralized structure is a shear zone that strikes N. 65°–75° W. and dips nearly vertically (fig. 42). The shear zone pinches and swells, but averages 10 ft (3.0 m) wide. Overburden obscures its extensions, but topographic depressions indicate it extends beyond the outcrop. Slices and wedges of altered metavolcanic wallrock constitute most of the shear zone. The zone contains an estimated 10 percent scattered sulfides, mainly along fractures. The sulfides, mostly in irregular blebs and masses, are sphalerite, galena, pyrite, and chalcopyrite. Some sulfide masses are as much as 1 ft (0.3 m) thick. Malachite, azurite, cerussite, and anglesite are the dominant secondary minerals. A second shear zone, as much as 8 ft (2.4 m) wide, intersects the west end of the main zone. This second zone locally contains limestone lenses as much as 5 ft (1.5 m) wide. Scattered pyrite, galena, and sphalerite blebs make up about 10 percent of the altered and sheared rock near the intersection of the two zones.
DEVELOPMENT: Two trenches and two pits
SAMPLING: Sample localities are shown on figure 42, and analyses listed in table 16. Five samples of the main shear zone averaged 0.36 percent copper, 2.79 percent lead, and 0.55 percent zinc.

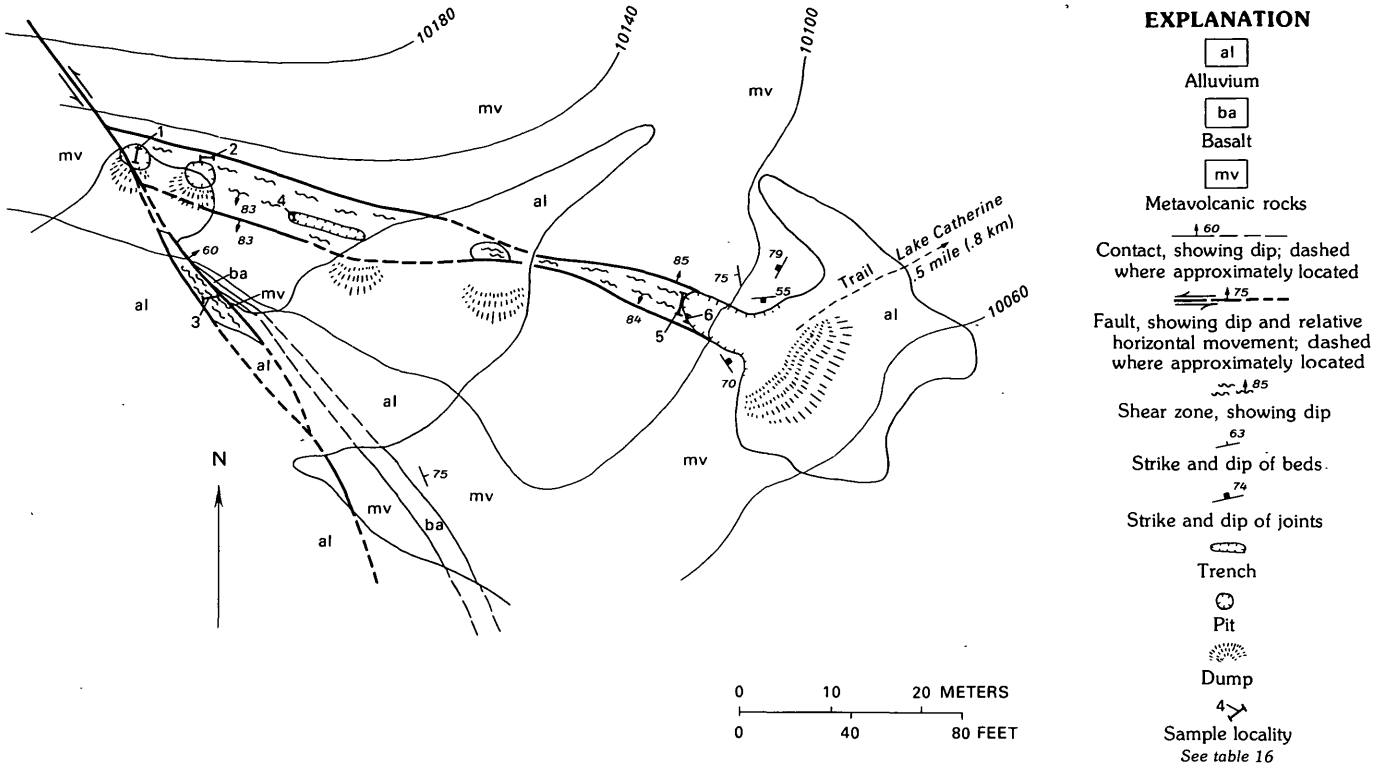


FIGURE 42.—Bliss prospect. See figure 37 for location. Contours in feet.

TABLE 16.—*Analytical data for Bliss prospect*
[Sample locations shown on figure 42. Tr, trace; N, none detected]

Sample No.	Type	Length (feet)[1]	Description	Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Copper (percent)	Lead (percent)	Zinc (percent)
1	Chip	5.5	Across brecciated metavolcanic rocks	N	N	Tr	0.03	0.04
2	do--	5.5	do	N	N	.73	2.2	.11
3	do--	5.0	Across limy metavolcanic rocks	N	N	.02	2.1	.42
4	do--	2.7	Across altered sheared metavolcanics with galena	N	N	.24	2.5	.08
5	do--	11.5	do	N	N	.23	2.4	.55
6	do--	3.0	Across sheared metavolcanic rocks with galena, sphalerite, and chalcopyrite	Tr	6.3	.96	10.7	2.7

[1]Metric conversions: feet × 0.3048 = meters; troy ounces per ton × 34.285 = grams per tonne.

RESOURCE ESTIMATE: The main shear zone is traceable along strike, between sample Nos. 1 to 6, for 500 ft (150 m) and averages 10 ft (3.0 m) wide. Within these limits the zone contains about 17,000 tons (15,400 t) of indicated paramarginal resources.

CONCLUSIONS: Additional development work to find extensions of the main shear zone is warranted.

NAME: Bluebell prospect

INDEX MAP NO.: Fig. 35

LOCATION: About 1 mi (1.6 km) southeast of Koip Peak

ELEVATION: 11,350 ft (3,459 m)

ACCESS: By trail 9 mi (4 km) northwest from the camp near Silver Lake

HISTORY: Work was done around the turn of the 20th century.

GEOLOGY OF DEPOSIT: Country rock is hydrothermally altered quartzite and quartzofeldspathic hornfels. Joints in these rocks strike N. 42° W., dip 85° SW. to vertically, and locally contain pyrite, sphalerite, and galena.

DEVELOPMENT: Three pits and one trench

SAMPLING: Seven grab and select samples were taken. Three grab samples contained no significant metallic values. Four select samples of hornfels containing sulfides had 2.1 to 3.3 troy oz of silver per ton (70–110 g/t), as much as 12.5 percent zinc, and 7.6 percent lead. One select sample contained 0.16 percent WO_3. A few samples assayed traces of gold.

CONCLUSIONS: The high metallic content in some select samples indicates that additional exploration is warranted.

NAME: Cattle Mountain claims
OWNER: D. Goodwin, Del Monte, Calif.
INDEX MAP NO.: Fig. 33, No. 16
LOCATION: On the west boundary of the study area in secs. 9 and 10, T. 5 S., R. 25 E., M.D.M.
ELEVATION: Workings on the claims range in elevation from 7,300 to 7,946 ft (2,225-2,422 m).
ACCESS: By road 4 mi (6 km) east from Clover Meadow
HISTORY: The claims were located in the 1940's and relocated as late as July 1965 by the present owner.
GEOLOGY OF DEPOSIT: Randomly oriented pegmatitic pods of coarse crystalline quartz and feldspar containing a few small "books" of biotite occur in the Mount Givens Granodiorite. The pods, as large as 20 by 20 ft (6.1 by 6.1 m), are in a north-south-trending zone. Some pods contain sparsely distributed heavily oxidized pyrite.
DEVELOPMENT: Six pits and open cuts with a maximum length of 15 ft (4.6 m) on pegmatite or quartz outcrops.
SAMPLING: Six samples were taken from the pits and cuts. Sample analyses showed no significant metallic contents.
CONCLUSIONS: The Cattle Mountain claims have no potential for metallic-mineral resources, nor are the pegmatite and quartz pods large enough to warrant mining for feldspar, mica, or silica resources.

NAME: Copper Queen prospect
INDEX MAP NO.: Fig. 35
LOCATION: On the north shore of the major northwesterly lake in the Alger Lakes basin
ELEVATION: 11,050 ft (3,368 m)
ACCESS: By trail 9 mi (14.5 km) northwest from Silver Lake
HISTORY: Prospecting appears to have been done around the turn of the 20th century.
GEOLOGY OF DEPOSIT: Pyrite occurs along fractures and joints in altered medium- to fine-grained gray to greenish-gray calcareous quartzite.
DEVELOPMENT: Two exploratory trenches
SAMPLING: One select sample was taken from each trench. The samples contained 0.7 and 1.3 troy oz of silver per ton (24 and 45 g/t), 0.26 and 0.52 percent lead, and 0.03 and 0.20 percent WO_3. Neither sample contained gold.
CONCLUSIONS: Because of its small size and apparent low grade, this body of mineralized rock cannot be considered a resource.

NAME: Crown Point-Nidever group

OWNER: E. H. McAffee, Oakhurst, Calif., and Otis Teaford, North Fork, Calif.

INDEX MAP NO.: Fig. 33, No. 7; fig. 34

LOCATION: Between Nydiver Lakes and Cabin Lake

ELEVATION: Elevations of workings range from 9,200 to 10,000 ft (2,800–3,000 m).

ACCESS: By trail 8 mi (13 km) west from Agnew Meadows

HISTORY: The Crown Point-Nidever group (fig. 34), including the Crown Point-Nidever prospect east of Nydiver Lakes, the Mike No. 2 prospect west of Cabin Lake, and the Nelson adit, were located by D. C. Nidever in 1912. In 1930, the Treadwell-Yukon Co. acquired the group and performed substantial exploration work, including extensive trenching (fig. 43) and some diamond drilling of the Crown Point-Nidever prospect. Only minor assessment work had been subsequently performed on the group until 1955, when the Climax Molybdenum Co. acquired a lease option. In the summer of 1956, the company conducted an exploration program supported by Defense Minerals Exploration Administration (DMEA) Contract IDM-E958, but the lease option was subsequently dropped. Annual assessment work was performed at least through 1975.

PREVIOUS PRODUCTION: In 1940, about 5.8 tons (5.3 t) of copper-zinc-rich tactite was mined and shipped to the American Smelting and Refining Co.'s (ASARCO) smelter at Selby, Calif., for testing.

GEOLOGY OF DEPOSIT: Tactite zones occur within metasedimentary and metavolcanic rocks of the Ritter Range roof pendant. The zones are typically lens shaped, trend north-northwest, and dip steeply northeast. Within the tactite zones, iron-rich sphalerite (marmatite), galena, chalcopyrite, arsenopyrite, and pyrite occur as massive stringers and pods and as irregularly distributed disseminations. Iron oxides, the alteration products of pyrite, stain the tactite. Garnet, epidote, iron-rich amphibole, calcite, and quartz are the major gangue minerals.

DEVELOPMENT: The deposits have been explored by numerous prospect pits and short adits (fig. 34). The Crown Point-Nidever prospect has been developed by trenches, shallow shafts, and 3,326 ft (1,014 m) of diamond drilling (fig. 44). Three prospect pits, a trench, and four adits, north of Shadow Creek and near the Crown Point-Nidever prospect, also are on small tactite lenses. The Mike No. 2 prospect (fig. 45) has 16 pits and trenches, one 10-ft (3.0 m)-long adit, and a caved adit. Below this prospect are a 75-ft (23 m)-long adit (Nelson adit, fig. 46), two trenches, and three pits or cuts that explore tactite pods.

SAMPLING: A total of 97 samples were taken from the Crown Point-Nidever group. Sample localities are shown on figures 44, 45, and 46; corresponding analyses are listed in tables 17, 18, and

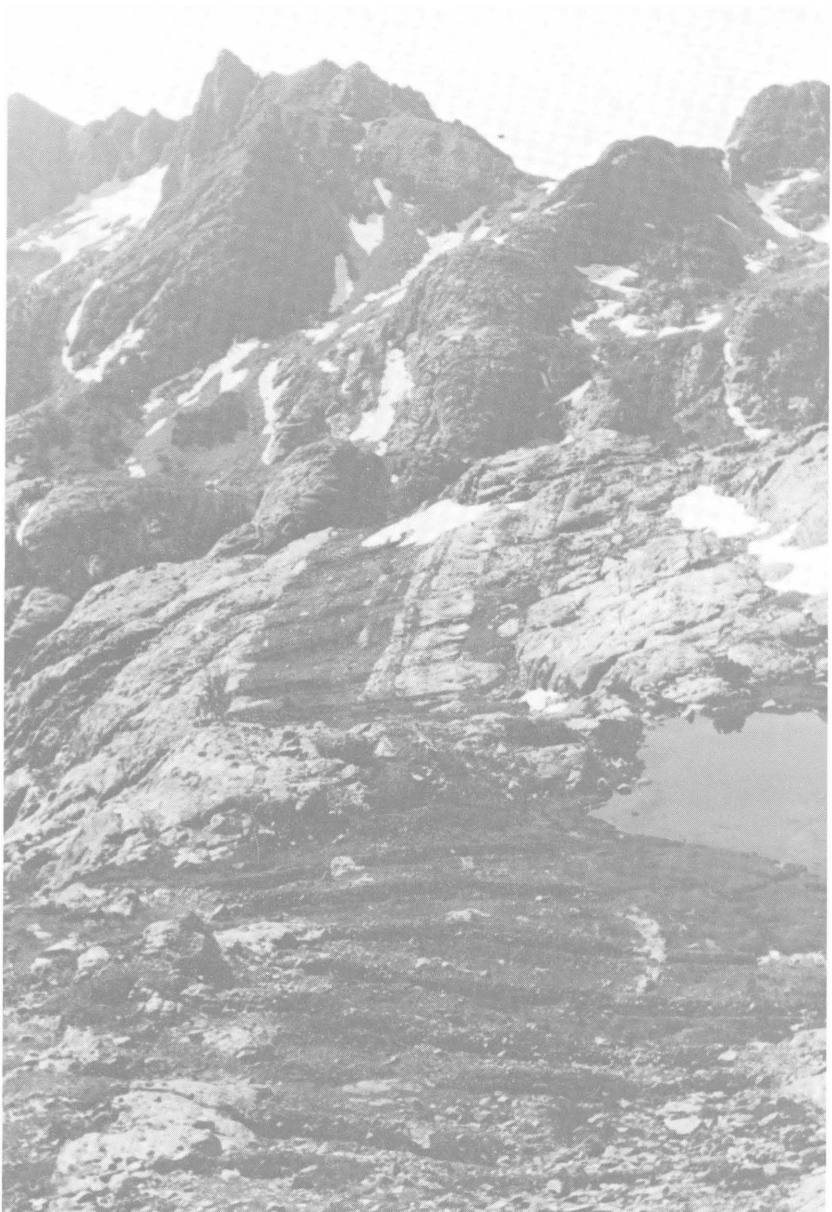


FIGURE 43.—Exploration trenches on Crown Point-Nidever prospect.

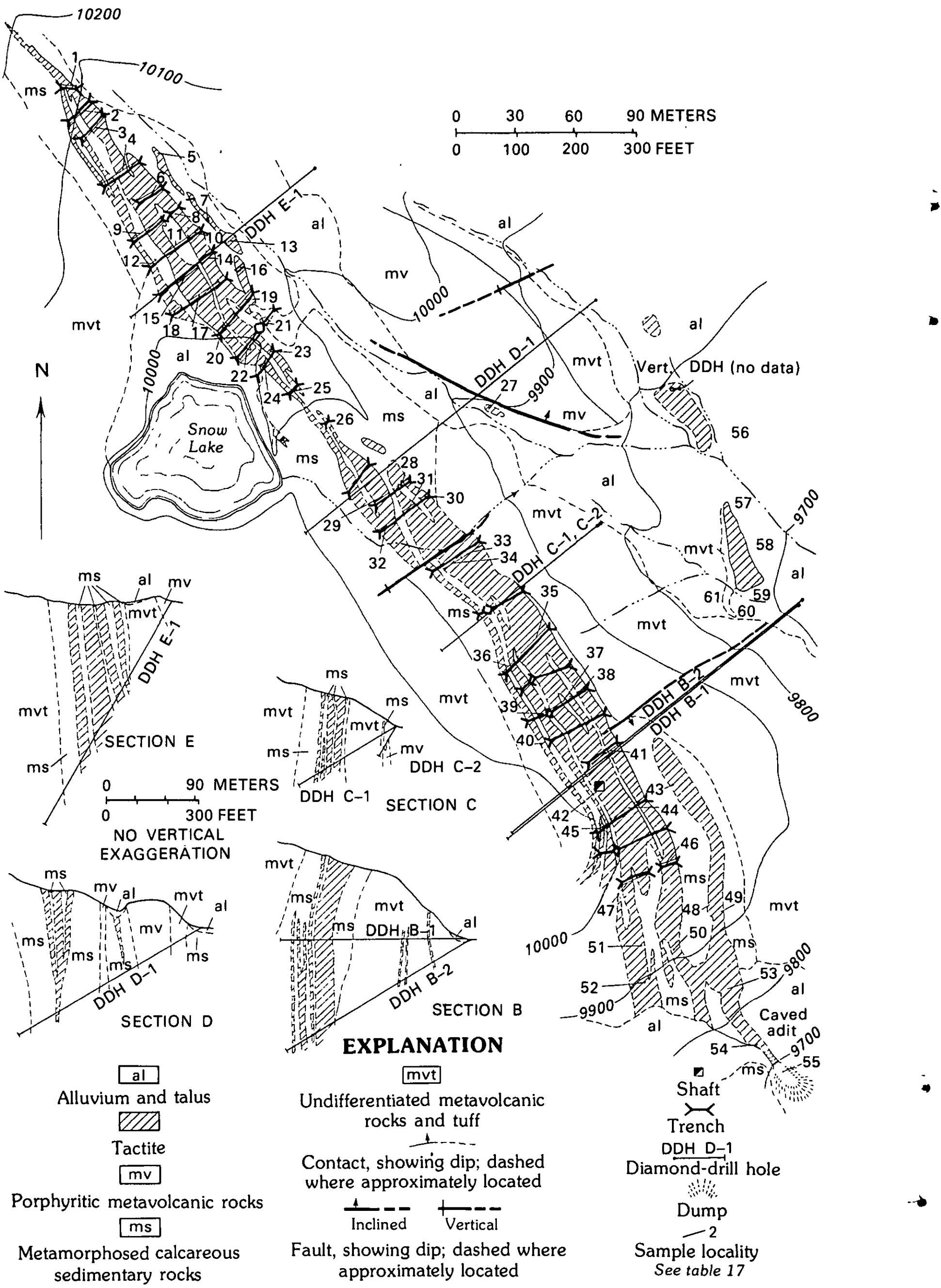


FIGURE 44.—Crown Point-Nidever prospect. See figure 34 for location. Contours in feet. Topography and drill-hole data from Climax Molydenum Co. report; cross sections and geology modified in part from company maps.

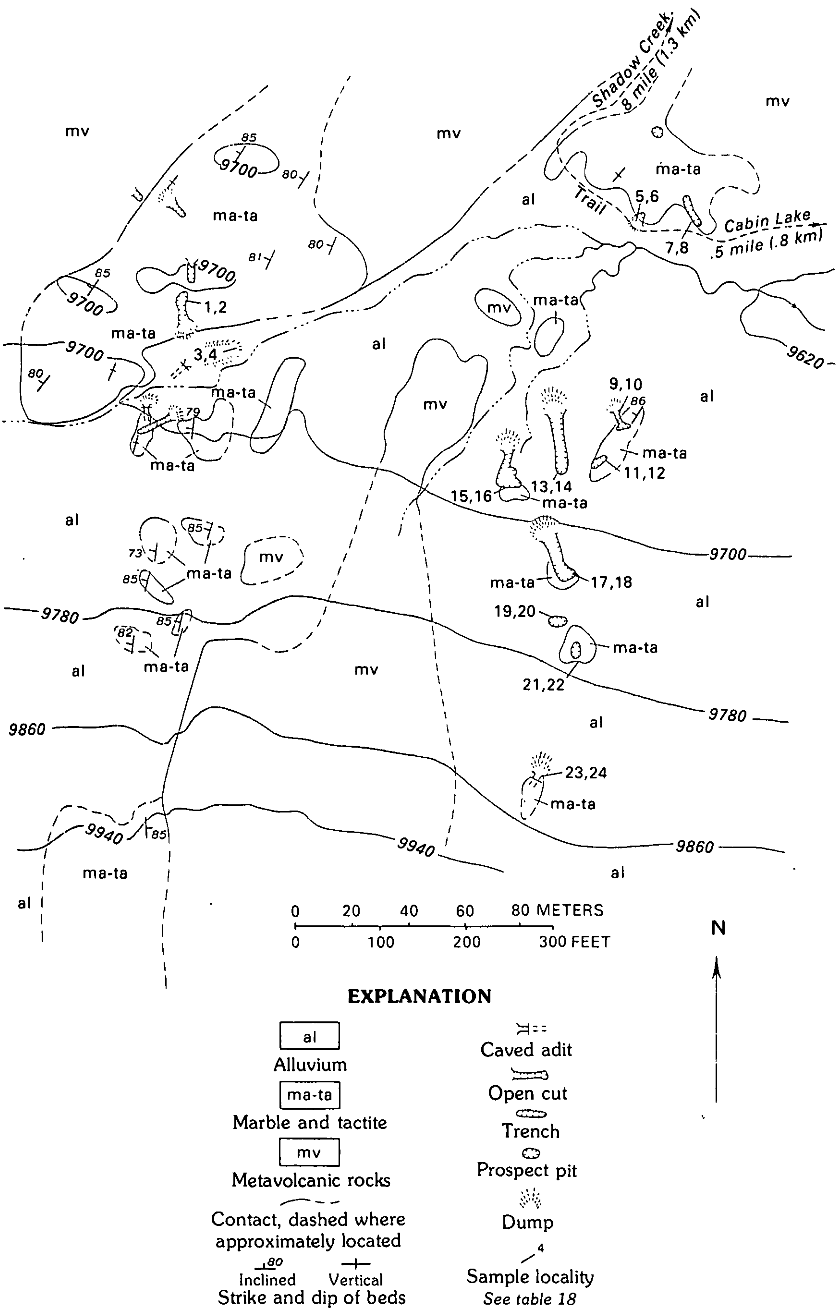


FIGURE 45.—Mike No. 2 prospect. See figure 34 for location. Contours in feet.

19. Most of the 58 chip samples from the Crown Point-Nidever prospect (table 17) were cut along existing trenches, but a few were taken across untrenched parts of the deposit. No attempt was made to sample high-grade areas selectively. The weighted-average grade for the north lens is 1.85 troy oz of silver per ton (55.5 g/t), 0.33 percent copper, 0.78 percent lead, and 3.25 percent zinc. For the south lens, the weighted-average grade is 0.46 troy oz of silver per ton (14 g/t), 0.12 percent copper, 0.21 percent lead, and 1.43 percent zinc. Data for resource calculation included assay results from 95 drill-hole samples. Subsurface data from the Climax-DMEA drilling program indicate continuity at depth, but the massive sulfide pods, evident at the surface, change

TABLE 17.—*Analytical data for Crown Point-Nidever prospect*
[Sample locations shown on figure 44. Tr, trace; N, none detected]

Sample				Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Copper (percent)	Lead (percent)	Zinc (percent)
No.	Type	Length (feet)[1]	Description					
1	Chip	25.0	Across banded red-brown tactite with visible sulfides	Tr	7.0	1.34	2.49	8.71
2	do	50.0	do	Tr	1.7	.56	.41	4.35
3	do	49.0	do	N	1.3	.51	.64	1.08
4	do	74.0	do	N	.7	.15	.30	1.68
5	do	8.0	do	Tr	1.1	.80	.17	6.10
6	do	44.0	do	.03	1.8	.68	1.32	2.90
7	Grab	--	Banded red-brown tactite with visible sulfides on dump	.05	10.0	.87	4.10	12.0
8	Chip	16.0	Across banded red-brown tactite with visible sulfides	Tr	.3	.29	.12	3.80
9	do	60.0	do	N	1.3	.11	2.10	1.50
10	do	22.2	do	N	1.6	.17	.58	2.03
11	do	10.5	do	N	1.2	.16	.35	1.97
12	do	20.0	do	Tr	.3	.005	1.06	1.20
13	do	18.0	do	.05	2.0	.20	1.40	7.30
14	do	25.0	do	.05	.3	.015	.14	1.30
15	do	35.0	do	.06	.2	.11	.098	2.80
16	do	18.0	do	N	.3	.91	.046	.033
17	do	59.0	do	Tr	2.1	.84	.40	7.86
18	do	21.5	do	N	.1	.033	.058	1.70
19	do	39.0	do	N	1.8	.079	.98	5.50
20	do	42.0	do	Tr	1.6	.30	.26	2.22
21	do	12.0	do	N	14.3	.091	3.10	2.50
22	do	55.0	do	N	2.2	.22	.51	3.0
23	do	12.0	do	Tr	5.9	.097	1.0	.3
24	do	10.0	do	N	.7	.35	.13	5.60
25	do	7.5	do	Tr	1.1	.023	.35	1.20
26	do	7.0	do	Tr	3.2	.37	.72	7.10
27	do	6.0	do	.01	1.2	.092	.32	2.39
28	do	27.0	do	Tr	Tr	.028	.029	1.30
29	do	36.5	do	Tr	.9	.20	.12	3.40
30	do	22.0	do	Tr	.2	.026	.25	1.40
31	do	22.0	do	N	.2	.025	.058	1.94
32	do	25.0	do	Tr	2.0	.28	.31	2.31
33	do	26.0	do	Tr	N	.012	.060	2.50
34	do	10.0	do	N	.1	.013	.18	.23
35	do	69.0	do	N	Tr	.010	.043	.49

TABLE 17.—*Analytical data for Crown Point-Nidever prospect*—Continued

Sample No.	Type	Length (feet)[1]	Description	Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Copper (percent)	Lead (percent)	Zinc (percent)
36	Chip	15.0	Across banded red-brown tactite with visible sulfides	N	0.2	0.004	0.099	0.28
37	do	18.0	do	N	.3	.007	.093	1.52
38	do	33.5	do	N	.1	.025	.11	2.40
39	do	16.0	do	N	N	.033	.053	1.10
40	do	3.0	do	Tr	.1	.060	.030	1.30
41	do	57.0	do	N	.1	.012	.71	1.20
42	do	3.0	do	N	.4	.41	.068	6.50
43	do	10.0	do	N	Tr	.021	.13	.25
44	do	10.0	do	Tr	.2	.71	.017	3.30
45	do	5.0	do	N	.3	.018	.047	1.90
46	do	34.0	do	Tr	Tr	.011	.085	.28
47	do	45.0	do	Tr	N	.063	.050	.34
48	do	6.0	do	.1	.9	.11	1.80	.76
49	do	20.0	do	N	N	.008	.040	.21
50	do	15.0	do	N	.1	.038	.11	.25
51	do	18.0	do	N	Tr	.005	.043	.078
52	do	10.0	do	N	2.9	.99	.58	3.50
53	do	7.0	do	Tr	.8	.52	.055	8.80
54	do	8.0	do	N	5.7	1.30	.92	.51
55	Grab	--	Banded red-brown tactite with visible sulfides	N	4.5	4.0	.051	3.40
56	Chip	13.2	Across banded red-brown tactite	N	.1	.021	.010	.075
57	do	3.5	do	Tr	.5	.11	.053	.19
58	Grab	--	Banded red-brown tactite from dump	Tr	.2	.072	.017	.082
59	Chip	19.0	Across banded light- to medium-red-brown tactite	N	N	.002	.006	.091
60	do	6.0	Across dark-red-brown tactite	N	N	.034	.019	.051
61	do	10.0	Across banded red-brown and green (epidote) tactite	N	.1	.007	.003	.015

[1]Metric conversions: feet × 0.3048 = meters; troy ounces per ton × 34.285 = grams per tonne.

TABLE 18.—*Analytical data for Mike No. 2 prospect*

[Sample locations shown on figure 45. Tr, trace; N, not detected]

Sample No.	Type	Description	Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Lead (percent)	Zinc (percent)
1	Grab	From hornfels containing galena	N	0.30	0.91	0.57
2	Select	do	N	N	.35	.47
3	Grab	From hornfels containing chalcopyrite, stains of malachite and azurite	N	.90	1.4	.59
4	Select	do	.01	.90	1.2	1.9
5	Grab	From hornfels containing sphalerite, galena, pyrite, stains of malachite	Tr	Tr	.040	.077
6	do	From hornfels containing galena, garnet, epidote, actinolite, and quartz	N	.40	.22	.22
7	Select	do	.01	.30	.050	.026
8	do	do	N	3.5	2.9	.67
9	Grab	From hornfels containing sphalerite, galena, pyrite, chalcopyrite, bornite, stains of malachite and azurite	N	.83	1.2	.098

TABLE 18.—*Analytical data for Mike No. 2 prospect*—Continued

Sample No.	Type	Description	Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Lead (percent)	Zinc (percent)
10	Select	From hornfels containing sphalerite, galena, pyrite, chalcopyrite, bornite, stains of malachite and azurite	N	.87	1.2	.34
11	Grab	From hornfels containing sphalerite, galena	Tr	.57	1.1	.11
12	Select	do	Tr	.30	.60	.15
13	Grab	do	N	.10	.065	.11
14	Select	do	N	.40	.28	.11
15	Grab	From hornfels containing sphalerite, galena, chalcopyrite, pyrite	N	.80	2.5	2.1
16	Select	do	Tr	1.8	3.2	9.6
17	Grab	From hornfels containing sphalerite, galena, chalcopyrite, stains of malachite	Tr	.55	4.2	1.8
18	Select	do	Tr	1.4	5.0	4.0
19	Grab	From hornfels containing chalcoprite, stains of malachite and azurite	N	.2	.030	.325
20	Select	do				
21	Grab	do	N	N	.025	.12
22	Select	do	Tr	1.6	.79	.13
23	Grab	From hornfels containing sphalerite, galena, molybdenite, stains of malachite and azurite	N	.76	1.2	.093
24	Select	do	Tr	1.8	1.4	.051

[1]Metric conversion: troy ounces per ton × 34.285 = grams per tonne.

TABLE 19.—*Analytical data for Nelson adit*

[Sample locations shown on figure 46. Tr, trace; N, not detected]

Sample No.	Type	Length (feet)[1]	Description	Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Lead (percent)	Zinc (percent)
1	Select	--	From calc-silicate hornfels containing galena	Tr	0.1	9.37	1.60
2	Grab	--	do	N	.1	.049	.13
3	Select	--	From calc-silicate hornfels with sphalerite and galena from dump	Tr	.62	1.60	1.10
4	Chip	20.0	Across calc-silicate hornfels with pyrite, malachite, and azurite	N	.1	.040	.045
5	do	6.0	Across calc-silicate hornfels containing galena and chalcopyrite	N	Tr	1.42	2.47
6	do	6.0	do	Tr	5.0	5.46	1.09
7	do	13.0	Across quartz vein containing galena	0.01	4.1	1.07	1.40
8	do	18.0	Across calc-silicate hornfels and quartz containing galena	Tr	1.3	1.7	1.30
9	do	10.0	Across calc-silicate hornfels	N	N	.39	1.10
10	do	1.5	Across siliceous calcite vein	Tr	4.0	.080	.070
11	do	7.0	Across fine-grained calc-silicate hornfels with a trace of sulfides	Tr	N	.20	.15
12	do	4.0	do	N	.1	.18	.081

[1]Metric conversions: feet × 0.3048 = meters; troy ounces per ton × 34.285 = grams per tonne.

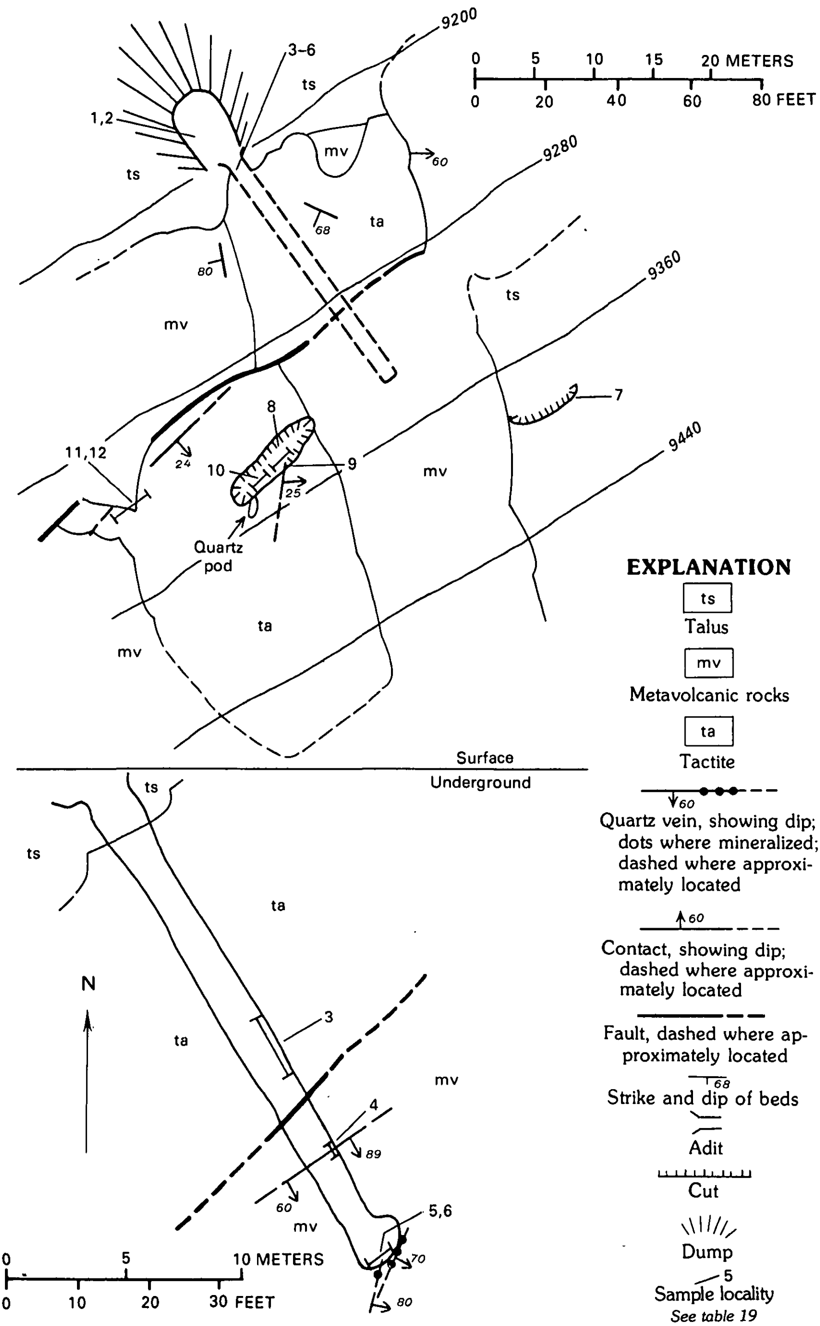


FIGURE 46.—Nelson adit. See figure 34 for location. Contours in feet.

rapidly with depth into lower grade disseminations and veinlets. Grade of the north lens at depth is based on 27 assays of drill hole E-1 over a high-angle intercept of 244 ft (74 m). The weighted-average grade is 0.63 troy oz of silver per ton (19 g/t), 0.03 percent copper, 0.17 percent lead, and 2.63 percent zinc. Grade of the south lens at depth is based primarily on a weighted average of 68 samples taken from drill holes B-1, B-2, C-1, and D-1, and 8 surface samples from south of drill hole B-1. The values are: 0.44 troy oz of silver per ton (13.2 g/t), 0.06 percent copper, 0.11 percent lead, and 1.30 percent zinc. A total of 24 samples were from the Mike No. 2 prospect (table 18). Select samples contained as much as 3.5 troy oz of silver per ton (120 g/t), 5 percent lead, and 9.6 percent zinc. Two select samples had as much as 0.01 troy oz of gold per ton (0.34 g/t). Analyses for 12 samples from the Nelson adit and nearby workings are listed in table 19. They contained as much as 5.0 troy oz of silver per ton (170 g/t), 9.37 percent lead, and 2.47 percent zinc.

RESOURCE ESTIMATE: Table 20 summarizes submarginal resources in the Crown Point-Nidever prospect from available geologic and analytical data. Indicated resources are based on a northern block that averages 750 ft (229 m) long, 61 ft (19 m) thick, and 370 ft (113 m) deep, plus a southern block that averages 1,250 ft (381 m) long, 85 ft (26 m) thick, and 405 ft (123 m) deep. Inferred tonnages are projected to approximately 700 ft (213 m) and consist of a northern block with dimensions of 750 ft (229 m) long, 61 ft (19 m) wide, and 370 ft (113 m) deep, plus a southern block 1,200 ft (366 m) long, 80 ft (24 m) thick, and 250 ft (76 m) deep. No gold resource is reported in the table because no accurate weighted average for the low, erratic values could be derived. However, it appears that the average gold content is well below 0.01 troy oz per ton (0.3 g/t).

CONCLUSIONS: Selective mining of high-grade areas would raise the tactite grade substantially, but decrease the tonnage. Thus, the deposit is submarginal and will probably remain so unless zinc and silver prices rise drastically.

TABLE 20.—*Submarginal resources, Crown Point-Nidever prospect*

	Tons[1] (millions)	Silver (troy oz per ton)[1]	Copper (percent)	Lead (percent)	Zinc (percent)
Indicated	5.4	0.6	0.1	0.2	1.9
Inferred	3.7	.5	.04	.1	1.9
Total	9.1				

[1]Metric conversions: tons × 0.907 = tonnes; troy ounces per ton × 34.285 = grams per tonne.

NAME: Dike Creek prospect
INDEX MAP NO.: Fig. 39
LOCATION: At the head of Dike Creek, a tributary of the North Fork San Joaquin River
ELEVATION: About 10,600 ft (3,230 m)
ACCESS: By trail 13 mi (21 km) north from Clover Meadow
HISTORY: The prospect was probably staked about 1914 in conjunction with the Big Lead and Eagle claims to the south.
GEOLOGY OF DEPOSIT: Persistent and massive quartz veins in diorite strike N. 10°-20° W. and dip 42°-58° NE. The veins, exposed for 3,300 ft (1,000 m) along strike, are as much as 10 ft (3.0 m) thick. The quartz veins are intermittently offset by east-west-trending structures. Pyrite occurs as disseminations and blebs in the quartz.
DEVELOPMENT: One small pit
SAMPLING: One grab and 12 chip samples were taken across the quartz vein. They contained no gold but as much as 0.4 troy oz of silver per ton (14 g/t) and 0.03 percent WO_3.
CONCLUSIONS: Sample analyses indicate that the prospect is not a mineral resource.

NAME: Eagle prospect
INDEX MAP NO.: Fig. 39
LOCATION: Near the head of the north fork of Iron Creek
ELEVATION: 10,200 ft (3,109 m)
ACCESS: By trail 14 mi (23 km) north from a road at Clover Meadow
HISTORY: The prospect consists of the Eagle Tungsten and Big Lead Tungsten Lode claims. These, and other adjacent, claims were surveyed for patent in September 1916. Later, these two claims were patented.
GEOLOGY OF DEPOSIT: The Eagle prospect is near a quartz monzonite-metavolcanic rock contact. A persistent vuggy quartz vein is mainly in the quartz monzonite. The vein strikes N. 40° W., dips 36°-45° NE., and ranges in thickness from less than 1 ft (0.3 m) to 4 ft (1.2 m). It appears to narrow and "horsetail" before being lost under talus to the southwest. At its northwest end, the vein penetrates metavolcanic rocks for a short distance. In the quartz vein, wolframite occurs in isolated, widely scattered blebs and very short stringers. An ultraviolet lamp indicates that masses of scheelite, as much as ⅛ in. (0.3 cm) long, occur in the blebs of wolframite. Lesser amounts of chalcopyrite and pyrite are commonly present near the blebs of wolframite.
DEVELOPMENT: An 18-ft (5.5 m)-long adit near the west end of

the quartz vein. Three trenches, approximately 30 ft (9.1 m) long, and small pits also on the vein.
SAMPLING: Ten chip and five grab samples were taken from the quartz vein. Chip samples across mineralized parts of the quartz vein had a weighted-average grade of 0.34 troy oz of silver per ton (12 g/t) and 0.24 percent WO_3. Grab samples contained as much as 0.5 troy oz of silver per ton (17 g/t) and 0.40 percent WO_3. One chip sample had 0.03 troy oz of gold per ton (1.0 g/t), but most contained only trace amounts.
CONCLUSION: Because of low scattered metallic content, the prospect has a low mineral-resource potential.

NAME: Grate Eastern prospect
INDEX MAP NO.: Fig. 35
LOCATION: About 1,000 ft (300 m) north of Alger Lakes
ELEVATION: 10,800 ft (3,292 m)
ACCESS: By trail 8 mi (13 km) northwest from Silver Lake
HISTORY: Development work was done before the turn of the century.
GEOLOGY OF DEPOSIT: Rocks near the workings are greenish-gray quartzofeldspathic hornfels containing varying amounts of pyrite, some chalcopyrite, and galena. The sulfides are along northwest-trending joints and fractures.
DEVELOPMENT: One caved shaft, one trench, and three partly caved adits
SAMPLING: A total of 13 samples were taken. The samples were mainly hornfels with pyrite, and some contained small amounts of visible galena. Two select samples had as much as 0.17 troy oz of gold per ton (5.8 g/t), 3.7 troy oz of silver per ton (127 g/t), and 1.1 percent lead. Six chip samples had no significant metallic content.
CONCLUSIONS: The prospect has almost no mineral-resource potential, on the basis of the low grade and limited extent of the deposits.

NAME: Heriford and Butler prospect
INDEX MAP NO.: Fig. 36
LOCATION: North of Agnew Meadows
ELEVATION: 8,800 ft (2,680 m)
ACCESS: By trail northwest 1 mi (1.6 km) from Agnew Meadows
HISTORY: Four claims were staked in 1923 and 1924 by Charles Heriford and B. Butler.
GEOLOGY OF DEPOSIT: Northeast- and northwest-trending quartz veins and lenses are in siliceous hornfels. Northwest-

trending veins are 2 to 6 in. (5–15 cm) thick. Pyrite and chalcopyrite locally occur in the veins and lenses. The most prominent structure is a lens north of the shaft (fig. 36). It trends northeast and is as much as 2 ft (0.6 m) thick.

DEVELOPMENT: One shallow shaft, one cut, and one caved adit

SAMPLING: Three select and two chip samples were taken. A chip sample of a narrow quartz vein in the cut contained 8.1 troy oz of silver per ton (280 g/t) and 1.6 percent copper. A select sample from a stockpile of the same rock contained 4.3 troy oz of silver per ton (150 g/t) and 0.72 percent copper. A sample of the most prominent lens had 0.1 troy oz of silver per ton (3.4 g/t). Sample assays showed no gold.

CONCLUSIONS: A small mineral-resource potential is indicated by high metallic content in select samples.

NAME: Independence prospect

INDEX MAP NO.: Fig. 35

LOCATION: Approximately 1,500 ft (450 m) northeast of the main Alger Lake

ELEVATION: 11,200 ft (3,414 m)

ACCESS: By trail 8 mi (13 km) northwest from Silver Lake, then across country

GEOLOGY OF DEPOSIT: An adit follows a 3- to 5-ft (0.9–1.5 m)-thick quartz vein in hornfels (fig. 47). The vein is along a fault that strikes N. 27° W. and dips vertically. Pods of pyrite and galena occur in the vein.

DEVELOPMENT: A 90-ft (27 m)-long adit with two 13-ft (4.0 m)-long crosscuts

SAMPLING: Nine chip samples were taken in the adit (table 21),

TABLE 21.—*Analytical data for Independence adit*

[Sample locations shown on figure 47. Tr, trace; N, not detected]

Sample				Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Lead (percent)
No.	Type	Length (feet)[1]	Description			
1	Chip	0.25	Across milky-quartz vein	N	N	Tr
2	do	2.5	Across siliceous shear zone	N	N	Tr
3	do	2.0	Across fault zone; hornfels, quartz, and gouge	N	N	Tr
4	do	2.5	Across hornfels	N	N	Tr
5	do	1.0	Across milky-quartz vein	N	.1	Tr
6	do	1.25	Across fault zone; milky quartz, hornfels, and gouge	Tr	13.9	1.2
7	do	2.5	Across milky-quartz vein stained with iron oxides	N	.4	Tr
8	do	4.0	Across milky-quartz vein	N	1.3	Tr
9	do	4.0	do	N	2.3	.65

[1]Metric conversions: feet × 0.3048 = meters; troy ounces per ton × 34.285 = grams per tonne.

and two select samples from the adit dump. The select samples contained as much as 5.7 troy oz of silver per ton (200 g/t) and 0.11 percent WO_3. Three chip samples (Nos. 7-9) of the main vein averaged 1.38 ounces silver per ton (47 g/t), with as much as 0.65 percent lead and 0.55 percent WO_3.

RESOURCE ESTIMATE: The main quartz vein averages 4 ft (1.2 m) in thickness and is exposed between sample localities 7 and 9. This vein contains an estimated 450 tons (408 t) of inferred submarginal resources.

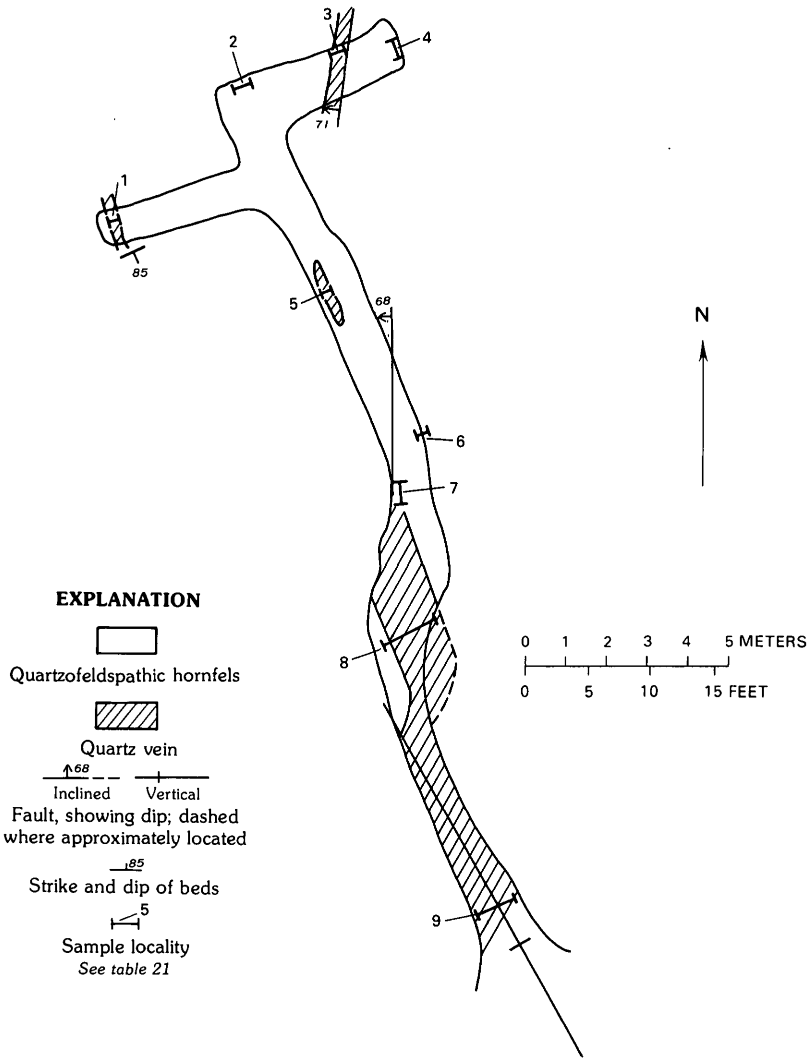


FIGURE 47.—Independence adit. See figure 35 for location.

CONCLUSIONS: Because the mineralized rock in the adit is of low grade and sporadic, the discovery of additional resources is unlikely.

NAME: Lakeside No. 2 claim
INDEX MAP NO.: Fig. 37
LOCATION: About 0.25 mi (0.4 km) east of northern Twin Island Lake
ELEVATION: About 9,800 ft (3,000 m)
ACCESS: By trail 17 mi (27.4 km) northeast from Clover Meadow
HISTORY: John Scales and Oliver Lines located the claim on August 13, 1955.
GEOLOGY OF DEPOSIT: A shear zone in metavolcanic rocks strikes about N. 65° W. and dips 60° SW. The zone is offset at numerous places along its 700 ft (213 m) of exposed strike length. It ranges in thickness from 1 to 10 ft (0.3–3.0 m). The zone is mostly filled by an andesitic dike that contains blebs and stringers of sulfides as much as 1/16 in. (2 mm) across. Sulfides, in decreasing order of abundance, are pyrite, arsenopyrite, chalcopyrite, and galena. The shear zone appears to be a northwestward extension of the Bliss prospect structure.
DEVELOPMENT: One 10-ft (3.0 m)-long cut
SAMPLING: Nine samples contained as much as 0.02 troy oz of gold per ton (0.7 g/t), 2.8 troy oz of silver per ton (96 g/t), 0.052 percent copper, 2.4 percent lead, and 0.34 percent zinc. Values in the surficial samples were probably diminished by weathering.
CONCLUSIONS: A small subeconomic resource exists on the claim.

NAME: Lucky Boy Prospect
INDEX MAP NO.: Fig. 35
LOCATION: Southeast of Alger Lakes
ELEVATION: 10,340 ft (3,152 m)
ACCESS: By trail 7 mi (11.3 km) northwest from Silver Lake
GEOLOGY OF DEPOSIT: An elongate quartz pod in metarhyolite. The quartz pod, 20 ft (6.1 m) long and as much as 1 ft (0.3 m) thick, contains a small amount of scattered pyrite and a trace of chalcopyrite.
DEVELOPMENT: A small pit
SAMPLING: A grab sample of metarhyolite and milky quartz and a select sample of milky quartz had no gold, no silver, and only a trace of copper.
CONCLUSIONS: The prospect has no mineral-resource potential.

NAME: Manzanita prospect
INDEX MAP NO.: Fig. 35
LOCATION: Approximately 1,700 ft (520 m) northeast of the lower part of Alger Lake
ELEVATION: 10,800 ft (3,290 m)
ACCESS: By trail 8 mi (13 km) northwest from Silver Lake
GEOLOGY OF DEPOSIT: Country rock is fractured greenish quartzofeldspathic hornfels. Iron-oxide-stained hornfels with disseminated pyrite was excavated in the only workings.
DEVELOPMENT: One trench, 14 ft (4.3 m) long, 5 ft (1.5 m) wide, and 5 ft (1.5 m) deep, trending N. 30° E.
SAMPLING: A select grab sample of iron-oxide-stained hornfels with some pyrite had no detectable gold or silver.
CONCLUSIONS: This prospect has no mineral-resource potential.

NAME: Marie Lakes prospect
INDEX MAP NO.: Fig. 33, No. 4
LOCATION: ¾ mi southeast of Mount Lyell
ELEVATION: 11,600 ft (3,540 m)
ACCESS: By trail 12 mi (19 km) from Agnew Meadows to Thousand Island Lake and Rush Creek, then across country 2.5 mi (4.0 km) to Marie Lakes
HISTORY: The area around the most southerly of the Marie Lakes apparently was staked in the late 1940's or early 1950's.
GEOLOGY OF DEPOSIT: Meta-andesite and granodiorite with felsic pegmatitic dikes underlie the prospect. Two granodiorite outcrops contain disseminated pyrite and chalcopyrite, and a third is coated with malachite.
SAMPLING: Five chip samples assayed no gold or silver and only minor amounts of copper.
CONCLUSIONS: No mineral-resource potential is evident, although the occurrence of disseminated chalcopyrite could be indicative of widespread mineralization of the porphyry copper type.

NAME: Mark prospect
OWNER: Denton B. Wolfe, Northfork, Calif.
INDEX MAP NO.: Fig. 33, No. 15
LOCATION: 6,000 ft (1,800 m) northeast of Green Mountain
ELEVATION: 7,900 ft (2,400 m)
ACCESS: By unimproved road 6 mi (10 km) east from Clover Meadow
HISTORY: Some claims were located under another name as early as 1932. The Mark prospect was located in 1950 by the present

owner. Annual assessment work has been done since the 1950's.

PREVIOUS PRODUCTION: A few tons of rock with high grades of copper and silver have been shipped for metallurgic testing.

GEOLOGY OF DEPOSIT: Quartzose fine- to medium-grained metasedimentary and tuffaceous metavolcanic rocks crop out on the prospect (fig. 48). The Mount Givens Granodiorite crops out nearby. The metamorphic rocks are intensely folded and faulted, with dominant structural trends striking northwest and dipping steeply southwest. Sulfide minerals occur along gash fracture veins (fig. 49), joints, breccia zones, and shear zones. One to ten percent disseminated sulfides locally occur along bedding planes within altered metavolcanic rocks. Chalcocite, bornite, pyrite, covellite, chalcopyrite, and tetrahedrite occur mainly as pods and stringers. Azurite and malachite are abundant near the surface. Magnetite, biotite, chlorite, hornblende, quartz, and epidote are accessory minerals. Two major groups of echelon gash fracture veins, 15 to 20 ft (4.6–7.1 m) thick, are exposed over a length of 400 ft (120 m). Both groups strike north-south and dip 40°-80° W. Individual veins are from 0.05 to 0.5 ft (0.02–0.15 m) thick and from 5 to 15 ft (1.5–4.6 m) long. They probably contain less than 10 percent sulfides. A prominent joint set, striking north-south and dipping 45° E., has sulfide lenses as thick as 1 ft (0.3 m). The major joints, which may be partly sheared, are 5 to 100 ft (1.5–30 m) apart. The joints are exposed throughout the prospect area. Breccia zones, which may be related to the jointing, are 20 to 40 ft (6–12 m) across at the main pit. Their boundaries are extremely irregular, and they may contain as much as 30 percent sulfides. Sheared metamorphic rocks that crop out among the cliffs northwest of the main pit contain about 5 percent scattered pyrite, chalcopyrite, bornite, and covellite. The copper minerals are in scattered blebs and stringers throughout the shear zones, which are at least 10 ft (3 m) wide.

DEVELOPMENT: The main working is a trench, approximately 150 ft (45 m) long and 25 ft (7.6 m) wide, in the major gash vein zone. Two other pits, 10 ft (3.0 m) and 15 ft (4.6 m) in diameter, plus one cut approximately 20 ft (6.1 m) long, are south of the main trench. There are other pits and trenches on the property, notably on the south knob. The latter trenches are on small tactite and magnetite zones in metamorphic rocks. Roads have been built to the main mineralized area.

SAMPLING: A total of 21 samples were taken from the gash vein zones in the main pit and adjacent areas, the nearby granitic dike, and the quartz veins and quartz-epidote rock northeast of the main pit area (table 22). Metallic content of samples from the

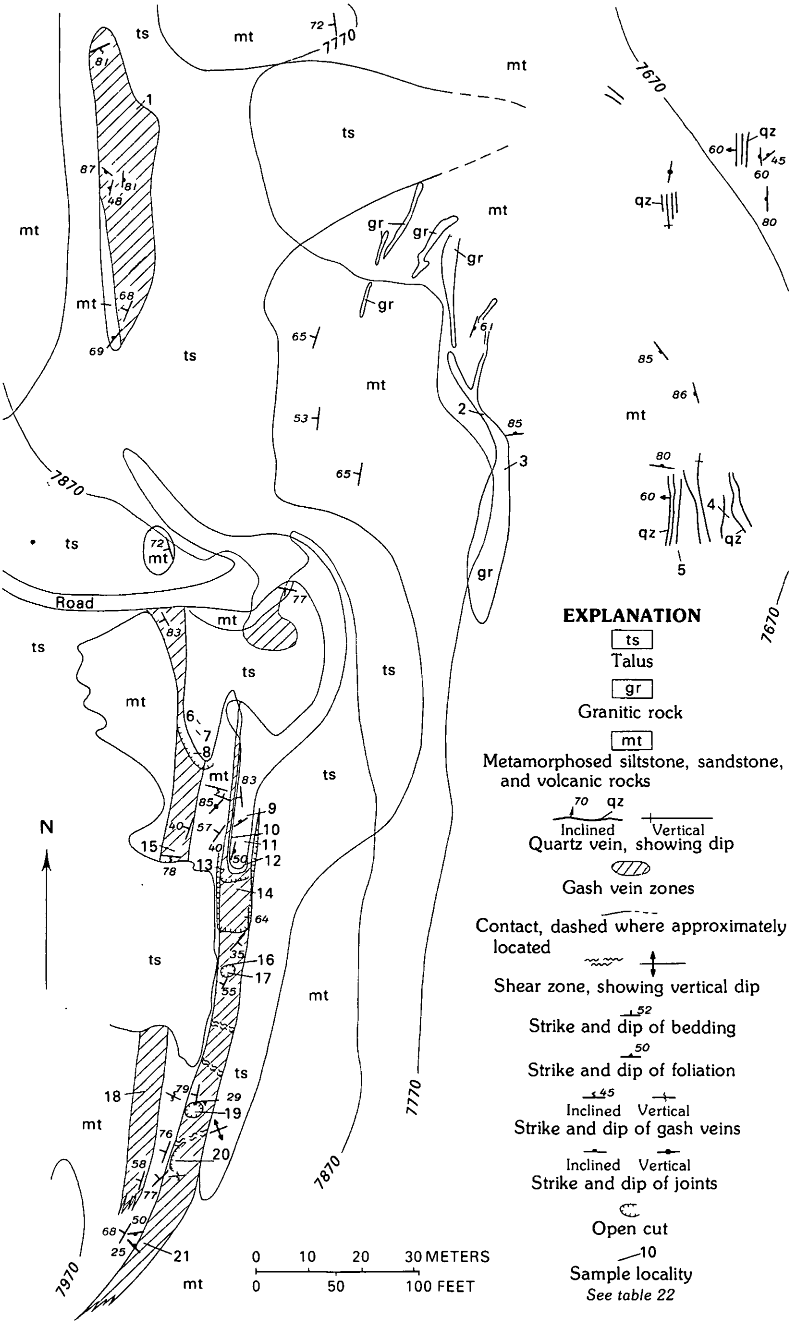


FIGURE 48.—Mark prospect. See figure 33 for location. Contours in feet.

main pit area (fig. 48, Nos. 9-14) ranged from 0.5 troy oz of silver per ton (17 g/t) with 0.23 percent copper, to 23.4 troy oz of silver per ton (802 g/t) with 13.9 percent copper. The high metallic content is from a select sample of hand-sorted highly mineralized rock found in the pit. These metallic contents are not indicative of the tenor of the mass of mineralized rock in the gash vein zone. The average metallic content, weighted by length, of chip samples taken from the pit and the adjacent gash vein zone to the west is 1.9 troy oz of silver per ton (65 g/t) and 1.12 percent copper. The character of the deposit indicates that selective mining, with hand sorting, could produce a higher grade of silver-copper ore.

RESOURCE ESTIMATE: Data derived from surface sampling and geologic mapping indicate that 30,000 to 40,000 tons (27,000-36,000 t) of paramarginal resources exist in the eastern gash zone. Samples 9-11, 13, 14, 16, 17, and 19-21 from the zone contained a weighted average of 1.9 troy oz of silver per ton (65 g/t) and 1.06 percent copper. The silver and copper minerals

FIGURE 49.—Mineralized rock from the Mark prospect. mv, metavolcanic rock containing layers of biotite and sulfide grains; br, breccia containing quartz, epidote, biotite, and sulfide masses; gv, gash vein surrounded by bleached zone.

TABLE 22.—*Analytical data for Mark prospect*

[Sample locations are shown on figure 48. Tr, trace; N, not detected; N.d., not determined]

Sample				Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Copper (percent)
No.	Type	Length (feet)[1]	Description			
1	Chip	35.0	Across gash vein zone	Tr	N	0.015
2	do	4.5	Across granitic dike	N	N	Tr
3	do	5.0	do	N	N	Tr
4	do	6.0	Across zone of quartz veins	Tr	Tr	Tr
5	do	15.0	Across two quartz veins and intervening country rock	Tr	N.d.	Tr
6	Grab	--	Pile of gash vein material on dump	.01	8.2	4.66
7	do	--	Brecciated metavolcanic and metasedimentary rocks with sulfides	N	1.0	.16
8	Chip	4.0	Across copper-carbonate-stained part of gash vein zone	Tr	.3	.39
9	Grab	--	Siliceous metasedimentary rocks in bottom of main pit	.01	.5	.23
10	Chip	2.2	Across gash vein zone	.01	3.2	1.74
11	Grab	--	Quartz-rich metasedimentary rocks in bottom of main pit	Tr	.6	.29
12	do	--	Stockpile of gash vein material in pit	.08	23.4	13.8
13	Chip	25.0	Across gash vein zone	.03	4.1	2.52
14	do	26.0	do	Tr	3.0	1.70
15	do	9.0	do	Tr	N	.025
16	do	3.5	Across gash vein zone with abundant sulfides	.01	6.8	3.52
17	do	14.0	Across gash vein zone	N	1.0	.33
18	do	18.0	do	N	Tr	.026
19	do	15.0	do	.01	1.4	.82
20	do	18.0	do	Tr	.4	.13
21	do	13.0	do	N	.1	.038

[1]Metric conversions: feet × 0.3048 = meters; troy ounces per ton × 34.285 = grams per tonne.

occur in pods and stringers, and so the grade could be raised substantially by selective mining and a minimum of sorting.

CONCLUSIONS: The probability of discovering additional paramarginal resources in the area is high.

NAME: Minarets magnetite prospect (Iron Mountain prospects)

OWNER: Minarets Holding Co., San Francisco, Calif., owner 1952. In 1975, the owner was unknown.

INDEX MAP NO.: Fig. 40

LOCATION: Adjacent to the south boundary of the Minarets Wilderness area, near the head of Cargyle Creek and the south fork of Iron Creek

ELEVATION: 10,500 ft (3,200 m)

ACCESS: By trail 14 mi (22 km) west from Devils Postpile National Monument or by trail 17 mi (27 km) northeast from Clover Meadow.

HISTORY: The prospect is on the Magnetic Iron Mine and Bull of the Woods Iron Mine claims, which were staked August 9, 1883. The claims, while held by the Noble Electric Steel Co., San Francisco, Calif., were surveyed for patent in August 1888 and patented in November 1914. In 1945, U.S. Bureau of Mines engineers conducted a diamond-drilling program on the property (Severy, 1946). Numerous examinations have been made by Government agencies and private companies.

PREVIOUS PRODUCTION: There is no recorded production, although a few tons of ore were probably taken for metallurgic testing.

GEOLOGY OF DEPOSIT: Metamorphosed volcanic, mafic and ultramafic, sedimentary, and intrusive granitic rocks, and magnetite masses, crop out near Iron Mountain (fig. 50). Felsic and mafic dikes, some of which are pegmatitic, and quartz veins occur. Most of the older rocks exhibit fault offsets and contorted folds. Some rocks contain small pyrite and copper-sulfide blebs, with limonite staining and thin coatings of secondary copper minerals on a few weathered outcrops. The major iron-bearing lens (fig. 50) is at least 1,500 ft (460 m) long and 175 ft (53 m) thick. It strikes N. 16°-18° W. and dips 80° NE. It thins to the north and, according to the U.S. Bureau of Mines interpretation of drilling in 1945, splits and thins at depth (Severy, 1946). Its southeast end is covered by overburden. Interpretation of two independent magnetometer surveys made by a private company (see Chapter B) and by the U.S. Bureau of Mines in this study indicates that the lens splits at the southeast end and terminates about 500 ft (150 m) from the site of sample No. 8 (fig. 40).

DEVELOPMENT: Two short adits, one trench, one shallow pit, and two diamond-drill holes

SAMPLING: Four samples came from surface exposures on or near the lens (table 23). In addition, eight unnumbered oriented samples of the magnetite and the country rock were taken for geomagnetic study (see Chapter B, this volume). In 112 samples analyzed for iron, assay values ranged from 1.7 to 64.4 percent (see fig. 40 for analyzed sample localities). Samples from two holes drilled by the U.S. Bureau of Mines in 1945 contained from 13.2 to 52 percent iron (Severy, 1946). The cross sections of figure

TABLE 23.—*Analytical data for Minarets magnetite prospect*

[Sample locations shown on figure 50. Tr, trace; N, not detected; –, not determined]

Sample				Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Iron (percent)
No.	Type	Length (feet)[1]	Description			
1	Chip	7.4	Across magnetite-bearing biotite schist	N	N	11.8
2	do	4.8	Across magnetite-bearing silicic rock	Tr	N	47.5
3	do	23.0	do	N	N	40.8
4	do	35.0	do	Tr	N	–

[1]Metric conversions: feet × 0.3048 = meters; troy ounces per ton × 34.285 = grams per tonne.

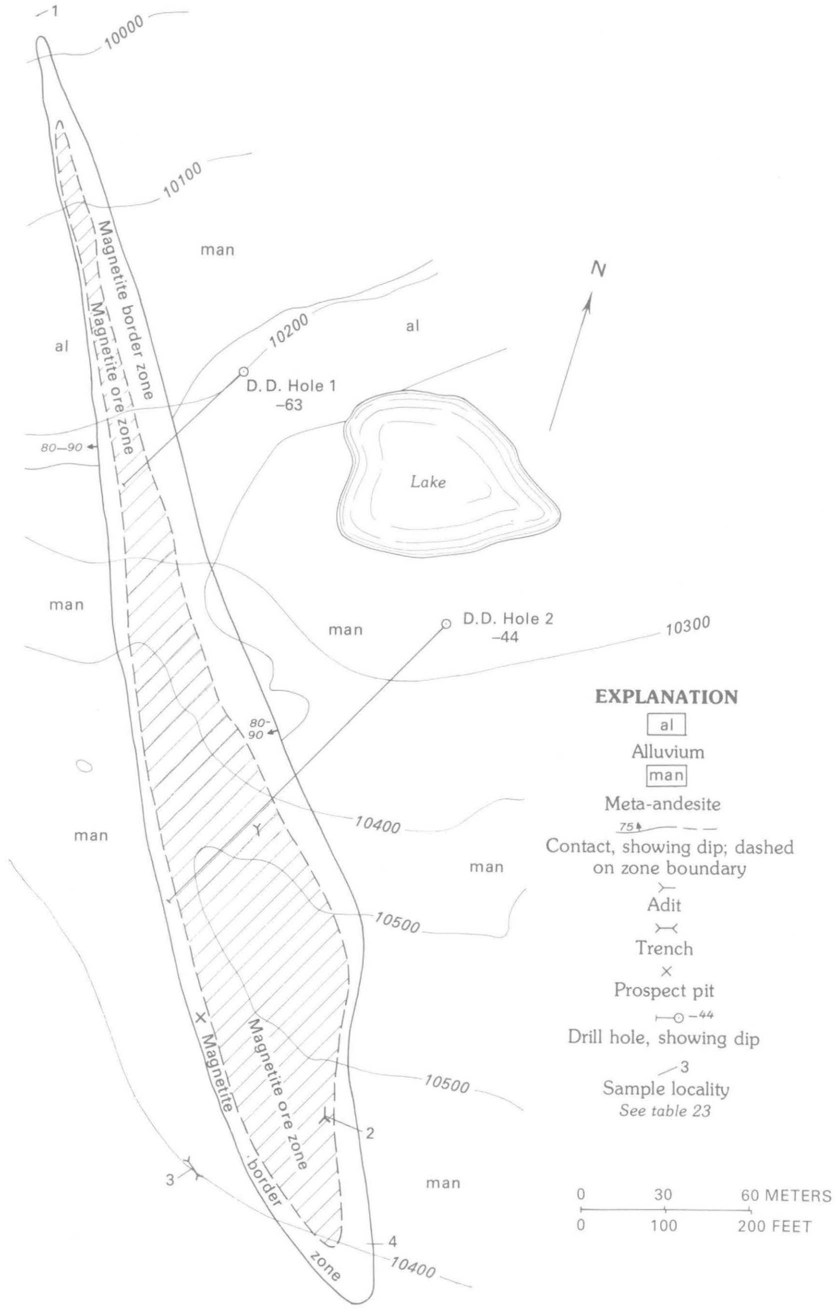
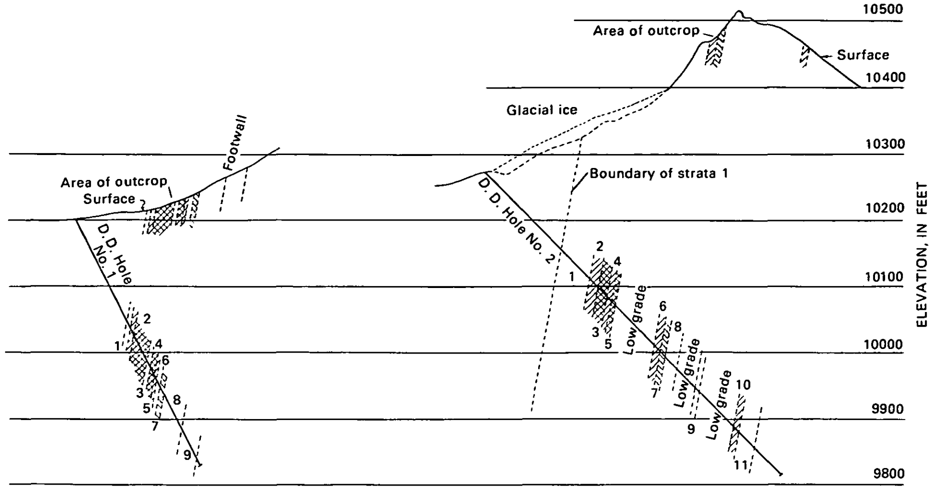


FIGURE 50.—Minarets magnetite prospect. Geology after Trask and Simons (1945). See figure 51 for drill-hole sections. Contours in feet.



EXPLANATION

Strata	True thickness, in feet	Iron, in percent
1	5.3	35.9
2	23.2	52.0
3	5.3	24.8
4	7.5	50.9
5	2.7	39.6
6	8.0	22.6
7	5.3	44.0
8	31.5	26.7
9	27.0	13.2

D.D.Hole	Bearing	Length, in feet	Dip, in degrees	Elevation of collar
1	S. 46° W.	415	−63	10200
2	S. 45° W.	641	−44	10265

30–40 percent iron

40–50 percent iron

More than 50 percent iron

0 25 50 75 METERS

0 100 200 FEET

Strata	True thickness, in feet	Iron, in percent
1	45.0	26.8
2	14.5	36.0
3	13.2	50.2
4	7.1	36.2
5	5.6	50.0
6	8.1	30.0
7	7.6	42.8
8	19.8	22.1
9	7.4	23.6
10	7.7	37.1
11	25.0	20.2

FIGURE 51.—Drill-hole sections, Minarets magnetite prospect. Data from Severy (1946). See figure 50 for location of drill-hole sections.

TABLE 24.—*Submarginal resources, Minarets magnetite prospect*

45 percent iron	2,604,000 tons measured[1]
	1,197,000 tons indicated
	749,000 tons inferred
Total	4,550,000
27 percent iron	2,200,000 tons measured
	1,100,000 tons indicated
	675,000 tons inferred
Total	3,975,000
Grand total	8,525,000

[1]Metric conversion: tons × 0.9072 = tonnes.

51 show assay results and mineralized zones for both drill holes.

RESOURCE ESTIMATE: Resource estimates were made by the U.S. Bureau of Mines after the completion of drill holes at the prospect (C. L. Severy, written commun., 1946). These estimates, listed in table 24, indicate less high-grade resources than those of Trask and Simon (1945), who did not have the benefit of the drill-hole data.

CONCLUSIONS: Because of the relatively low grade, small size, and inaccessibility of the iron deposits, further development of the Minarets magnetite prospect is unlikely.

NAME: Minarets prospect

OWNER: Held in 1974 by the Rev. Ralph E. York, Los Gatos, Calif.

INDEX MAP NO.: Fig. 34

LOCATION: South of Volcanic Ridge and near the head of the north fork of Minaret Creek

ELEVATION: 9,700 ft (2,960 m)

ACCESS: By trail 8 mi (12 km) northwest from the road at Devils Postpile National Monument

HISTORY: The original claims were staked shortly after 1906. Some workings were excavated shortly after location, and activity has continued sporadically since. The present claimant has been doing annual assessment work for the last few years.

PREVIOUS PRODUCTION: No production has been recorded. Sizes of dumps indicate a moderate amount of underground work in the areas of samples 1, 2, and 3 (fig. 52). Minor production may have resulted from this work.

GEOLOGY OF DEPOSIT: Metallic minerals, mainly sulfides of copper, lead, and zinc, occur in tactite bodies and metavolcanic rocks with bedded marble, near two converging faults. The most concentrated zones of metallic minerals are principally in fractures along the south fault (fig. 52).

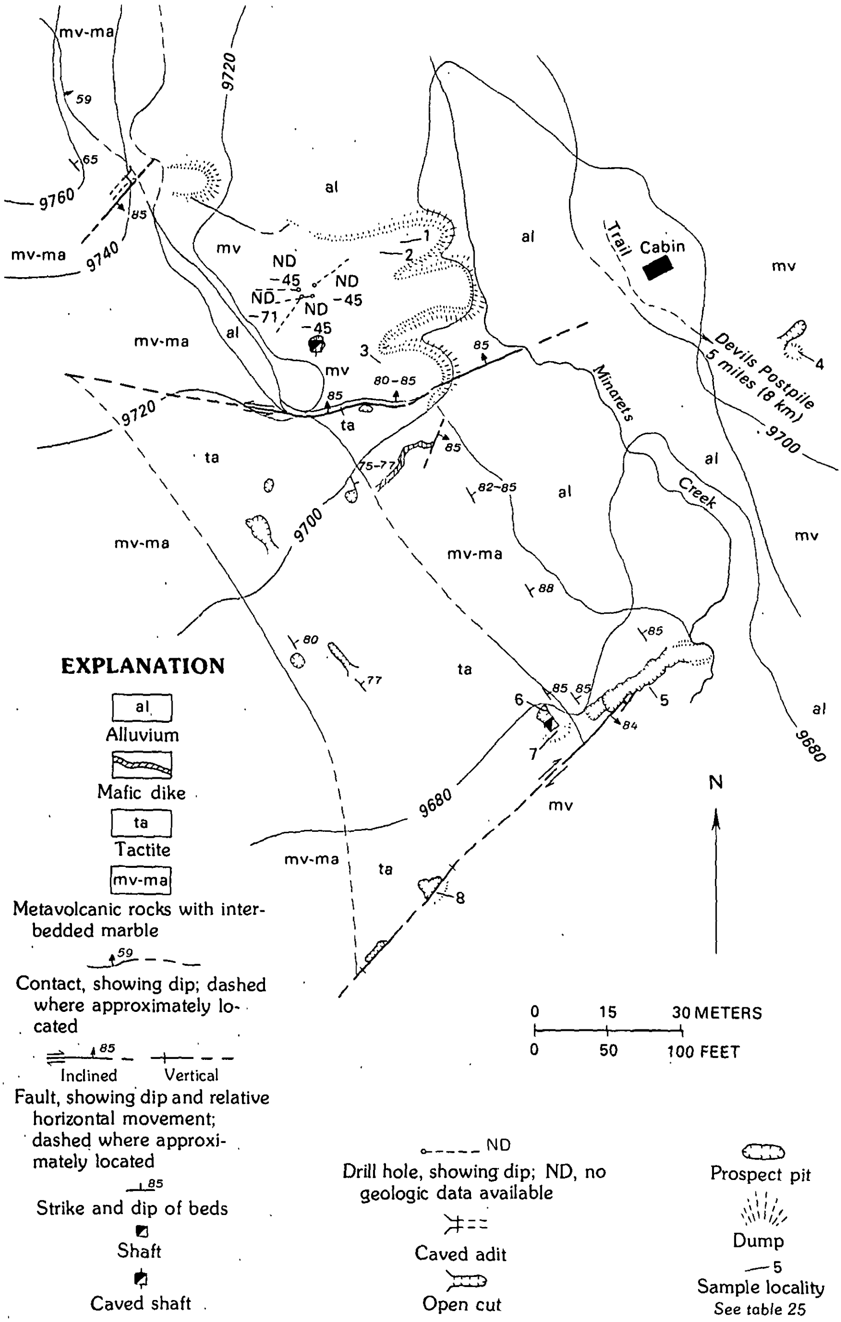


FIGURE 52.—Minarets prospect. See figure 34 for location. Contours in feet.

TABLE 25.—*Analytical data for Minarets prospect*
[Sample locations shown on figure 52. Tr, trace; N, none detected]

Sample			Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Copper (percent)	Lead (percent)	Zinc (percent)
No.	Type	Description					
1	Grab	Iron-oxide-stained metavolcanic rocks on main-shaft dump	N	0.10	Tr	0.07	0.11
2	do	do	Tr	Tr	Tr	.04	.08
3	do	Metavolcanic rocks and marble on dump of small shaft	N	.40	Tr	.28	.11
4	do	Sulfide-bearing metavolcanic rocks on dump of a small cut	.01	.30	Tr	.05	.26
5	do	Metavolcanic rocks and marble containing galena and sphalerite	N	.55	Tr	4.2	1.8
6	do	Highly iron oxide stained tactite from dump of shaft	Tr	1.4	.03	5.0	4.0
7	do	do	Tr	1.8	.01	4.2	1.8
8	do	Highly iron oxide stained tactite on pit dump	N	.80	.01	2.5	2.1

[1]Metric conversion: troy ounces per ton × 34,285 = grams per tonne.

DEVELOPMENT: One caved adit, two caved shafts, one water-filled shaft, four open cuts, and five pits constitute the major workings. Four diamond-drill holes with random bearings and inclined 45° and 71° from the horizontal were found north of the major caved shaft (fig. 52). No significant information could be obtained from available cores, which have been badly scattered.

SAMPLING: Eight samples were taken from the area of the main workings (table 25). These contained a maximum of 0.01 troy oz of gold per ton (0.35 g/t), 1.8 troy oz of silver per ton (61.7 g/t), 5.0 percent lead, and 4.0 percent zinc, with traces of copper.

CONCLUSIONS: Field observation and assay results show that the greatest concentration of metallic minerals occurs in a 2.5-ft (0.76 m)-wide zone along the south fault (fig. 52). A paramarginal resource of less than 7,500 tons of mineralized rock may exist along the south fault in the tactite and adjacent areas of the metavolcanic rocks with interbedded marble, including the area between samples 5 and 8 (fig. 52).

NAME: Mono Pass prospect
INDEX MAP NO.: Fig. 33, No. 1
LOCATION: On Mono Pass
ELEVATION: 10,800 ft (3,290 m)
ACCESS: By foot trail 3 mi (4.8 km) south from Tioga Pass road
HISTORY: The prospect includes three claims first located in 1879 (Russell, 1957): the Golden Crown Quartz mine, Ella Bloss Quartz mine, and Ella Bloss No. 2 Quartz mine (fig. 53). These claims were surveyed for patent in July 1884 and subsequently patented. Development work was done before the turn of the century. There

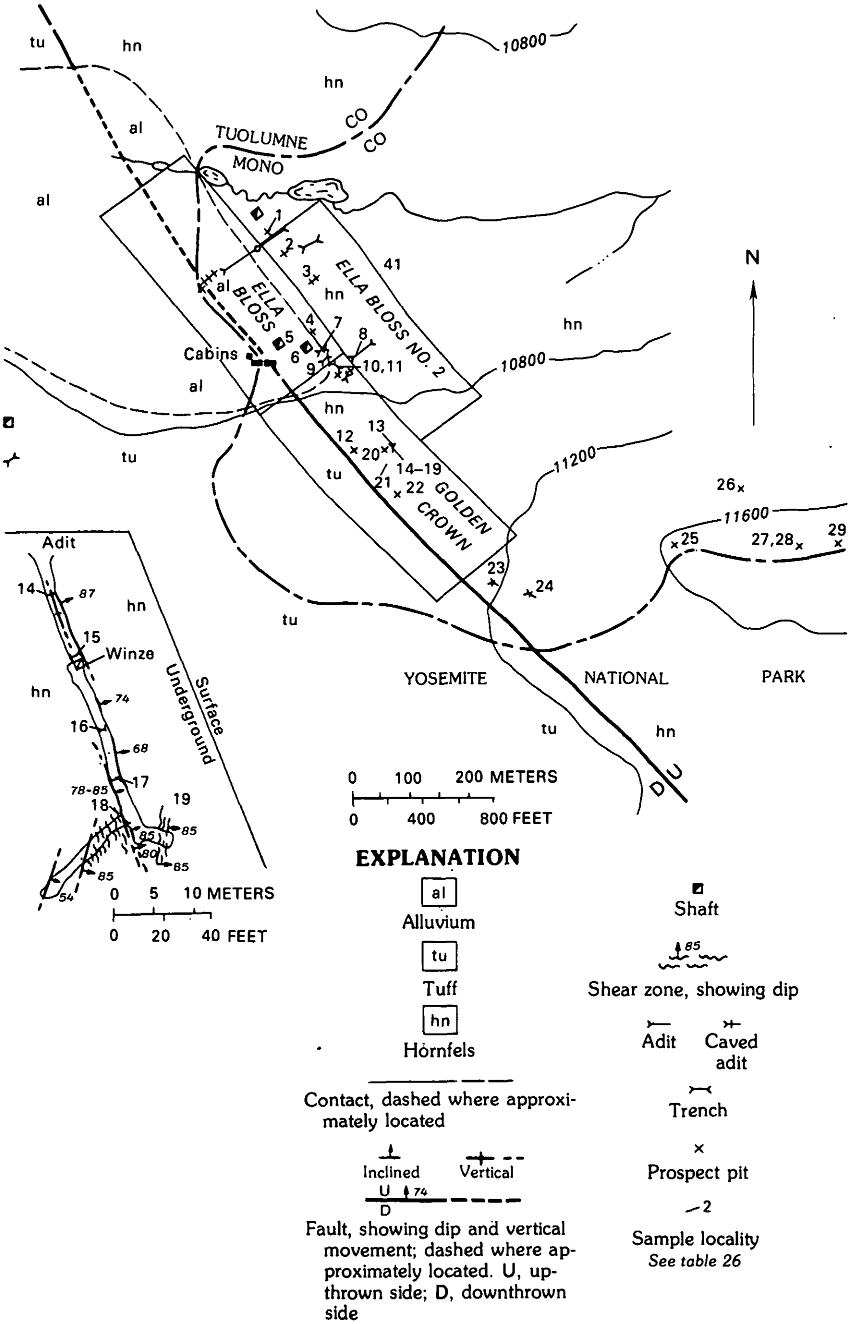


FIGURE 53.—Mono Pass prospects. Geology after Kistler (1966a). See figure 33 for location. Contours in feet.

is no evidence of recent work.

GEOLOGY OF DEPOSIT: Sulfide minerals, mainly pyrite, marcasite, and some arsenopyrite, occur in northwest-trending shear and fracture zones in hornfels. These zones are nearly parallel to a fault that strikes N. 30° W. Quartz is abundant in most shear zones, but sparse to adundant calcite veinlets parallel the prospect's main shear zone, exposed in the Golden Crown adit (fig. 53). A mineralized but less prominent shear zone is exposed in a pit 200 ft (60.9 m) west of the adit.

DEVELOPMENT: The Golden Crown adit, approximately 110 ft (34 m) long, with 45-ft (14 m) and 15-ft (4.6 m) crosscuts, is the major working on the Mono Pass prospect. Smaller workings include three shafts, two caved adits, and numerous pits and trenches.

SAMPLING: A total of 29 samples were taken. Sample localities are shown on figure 53, with corresponding analyses in table 26.

RESOURCE ESTIMATES: The main shear zone, in the Golden Crown adit, contains approximately 10,700 tons (9,700 t) of paramarginal resources. Sample Nos. 14–18, taken from the zone in the adit, and sample No. 21, from the surface expression of the zone, averaged 0.08 troy oz of gold per ton (2.7 g/t), 6.0 troy oz of silver per ton (210 g/t), and 0.11 percent copper. Spectrographic analyses indicate high arsenic and antimony contents (greater than 10,000 ppm in one sample), which may prove detrimental to metallurgic processing.

CONCLUSIONS: Additional development work could significantly increase the prospect's mineral-resource potential.

TABLE 26.—*Analytical data for Mono Pass prospect*

[Sample localities shown on figure 53. Tr, trace; N, not detected]

Sample				Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Copper (percent)
No.	Type	Length (feet)[1]	Description			
1	Grab	--	From glacial till in trench	Tr	N	0.06
2	Chip	2.0	Across quartz outcrop	Tr	N	.01
3	do	5.5	do	.01	N	Tr
4	Grab	--	From glacial till on pit dump	Tr	Tr	Tr
5	do	--	From sulfide-bearing siliceous hornfels on shaft dump	Tr	1.2	.01
6	do	--	From hornfels on shaft dump	Tr	N	Tr
7	do	--	From loose siliceous hornfels material in trench	Tr	.1	Tr
8	Chip	2.0	Across wall of trench in hornfels	Tr	.2	Tr
9	Grab	--	From broken siliceous hornfels in trench	.02	2.9	Tr
10	do	--	From sulfide-bearing siliceous hornfels on trench dump	.01	2.1	.03
11	Chip	6.0	Across quartz outcrop in trench	Tr	3.9	.02

TABLE 26.—*Analytical data for Mono Pass prospect*—Continued

Sample				Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Copper (percent)
No.	Type	Length (feet)[1]	Description			
12	do	5.0	Across sulfide-bearing hornfels in southeast wall of pit	0.08	13.5	0.24
13	Grab	--	From sulfide-bearing hornfels on adit dump	.08	18.3	.42
14	Chip	4.3	Across siliceous zone at adit portal	.06	1.7	.03
15	Chip	8.4	Across jointed pyrite-rich zone with calcite stringers	.07	7.7	.15
16	do	5.9	do	.09	10.9	.28
17	do	4.8	do	.05	5.6	.25
18	do	1.2	Across highly iron oxide stained zone in hornfels	.17	2.7	.12
19	do	1.4	Across pyrite-rich zone of hornfels	.02	N	Tr
20	do	5.2	Across hornfels in surface cut	.14	2.6	.03
21	do	4.8	Across pyrite-rich zone of hornfels outcrop	.12	2.6	.06
22	do	2.2	Across hornfels in south wall of open cut	.01	.8	.03
23	Grab	--	From hornfels on caved adit dump	Tr	Tr	Tr
24	Chip	10.0	Across quartz outcrop	N	Tr	Tr
25	Grab	--	From hornfels on pit dump	N	N	Tr
26	do	--	do	Tr	Tr	.02
27	do	--	do	N	.1	.07
28	do	--	From loose iron-oxide-stained hornfels	Tr	N	.02
29	do	--	From hornfels on pit dump	Tr	N	.14

[1]Metric conversions: feet × 0.3048 = meters; troy ounces per ton × 34.285 = grams per tonne.

NAME: Pat No. 1 claim
OWNER: H. C. Smith
INDEX MAP NO.: Fig. 37
LOCATION: At north end of upper Twin Island Lake
ELEVATION: 9,900 ft (3,000 m)
ACCESS: By trail 15 mi (24.1 km) northeast from Clover Meadow
HISTORY: The Pat No. 1 claim is believed to have been located originally in the 1920's as the Lake No. 1 claim, and relocated in 1957 under the present name.
GEOLOGY OF DEPOSIT: An andesitic dike and shear zone in metavolcanic rocks are along the hanging wall of a fault that strikes N. 70°-80° W. and dips from 80° NE. to vertical (fig. 54). The shear zone is as much as 10 ft (3.0 m) wide, and the dike as much as 40 ft (12 m) wide. Sulfides (pyrite, galena, and sphalerite) are in the shear zone, where they occur in widely spaced blebs and stringers. The dike has no sulfides. Metavolcanic rocks of the Ritter Range locally are randomly fractured, and, in places, the fractures are highly iron oxide stained. At sample locality No. 6 (fig. 54), pyrite occurs in most fractures.
DEVELOPMENT: Two prospect pits
SAMPLING: Localities for the 10 samples taken from the claim

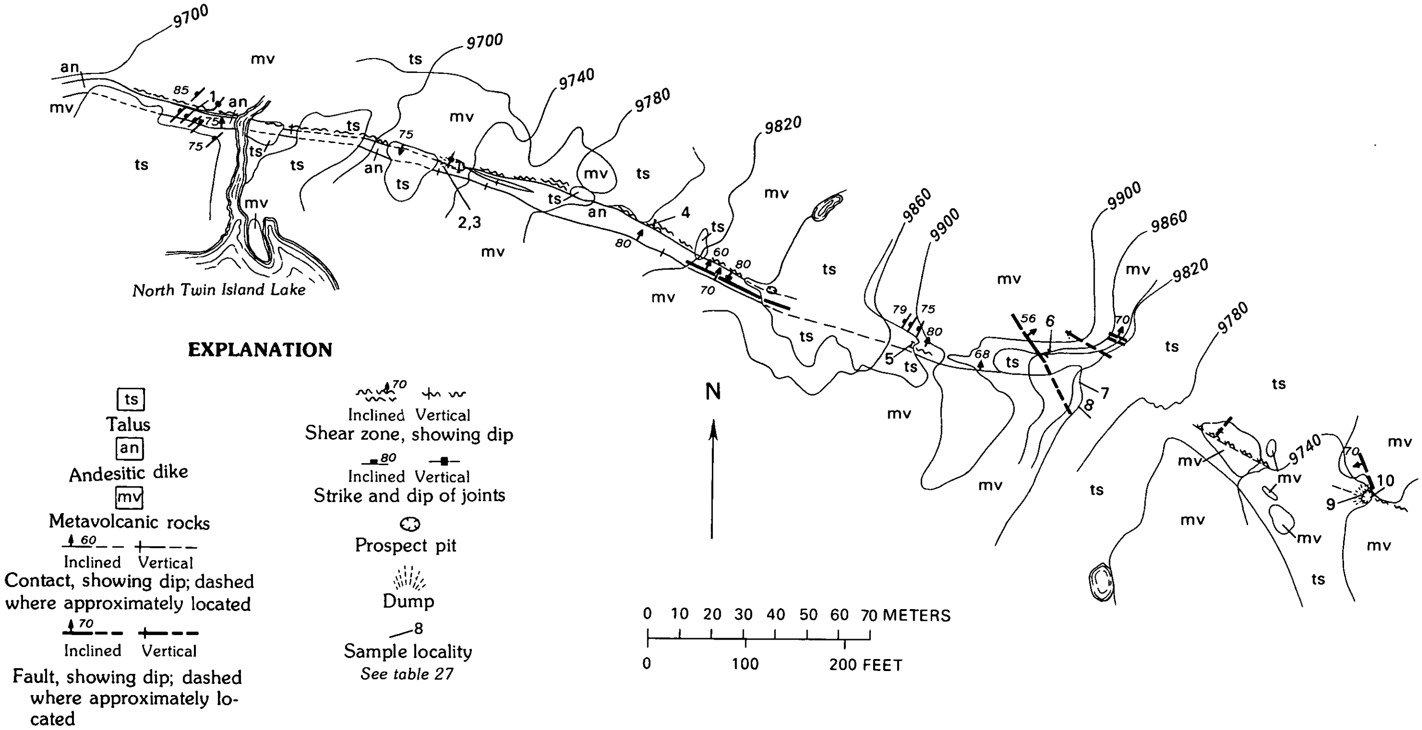


FIGURE 54.—Pat No. 1 claim. See figure 37 for location. Contours in feet.

TABLE 27.—*Analytical data for Pat No. 1 claim*

[Sample locations shown on figure 54. Tr, trace; N, none detected; -, not determined]

Sample No.	Type	Length (feet)[1]	Description	Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Copper (percent)	Lead (percent)	Zinc (percent)
1	Grab	--	From broken sheared rock	0.02	13.3	0.059	4.1	0.61
2	Chip	1.0	Across shear zone	Tr	5.7	.057	5.0	13.8
3	do	9.5	Across andesitic dike rock	N	.02	.008	.30	.20
4	do	7.0	Across shear zone	N	Tr	.005	.12	N
5	do	2.0	do	N	.4	.034	.66	N
6	do	7.0	do	N	.6	.005	1.6	N
7	do	20.0	Across sulfide-rich zone	N	.2	.009	.48	N
8	do	5.0	do	N	.1	.004	N	N
9	Grab	--	From mafic dike rock on pit dump	Tr	.9	.140	N	N
10	Chip	6.8	Across shear zone	-	.4	.013	N	N

[1]Metric conversions: feet × 0.3048 = meters; troy ounces per ton × 34.285 = grams per tonne.

are shown in figure 54; corresponding analyses are listed in table 27. The samples contained as much as 0.02 troy oz of gold per ton (0.69 g/t), 13.3 troy oz of silver per ton (456 g/t), 0.14 percent copper, 5.0 percent lead, and 13.8 percent zinc.

CONCLUSIONS: The sparse and irregular occurrence of metallic sulfide minerals in the shear zone and in fractures in the country rock preclude calculating a reliable resource estimate. The claim does, nevertheless, represent a small resource potential.

NAME: Prospect A

INDEX MAP NO.: Fig. 38

LOCATION: About 4,000 ft (1,200 m) south of Mount Lewis

ELEVATION: 11,000 ft (3,350 m)

ACCESS: By trail 5.5 mi (8.9 km) southeast from Tioga Pass road

GEOLOGY OF DEPOSIT: Country rock is thin-bedded quartzite with a strike of N. 44° W. and a dip of about 65° NE. A N. 44° W.-striking 50°-70° SW.-dipping narrow shear zone contains pyrite and chalcopyrite in a quartz-rich matrix.

DEVELOPMENT: An adit 6 ft (1.8 m) long with a 13-ft (4.0 m)-deep winze, and two small pits

SAMPLING: A select sample of the adit dump had no gold or silver, 0.71 percent copper, and less than 0.01 percent WO_3. One 5-ft (1.5 m)-long chip sample of quartzite with sulfides was without gold or silver but had 0.69 percent copper and less than 0.01 percent WO_3. One grab sample contained a trace of gold, 0.2 troy oz of silver per ton (6.7 g/t), and 0.17 percent copper.

CONCLUSIONS: A minor subeconomic resource of silver and copper exists on the prospect.

NAME: Prospect B
INDEX MAP NO.: Fig. 38
LOCATION: About 3,200 ft (980 m) northwest from Koip Peak
ELEVATION: 11,800 ft (3,600 m)
ACCESS: By trail 6 mi (9.7 km) southeast from Tioga Pass road
GEOLOGY OF DEPOSIT: Country rock is fractured dark-gray shale, striking about N. 60° W. and dipping about 65° NE. Widely spaced narrow quartz stringers cut the country rock at random angles. Pyrite in narrow veinlets, $\frac{1}{16}$ to $\frac{1}{8}$ in. thick (0.15-0.32 cm) thick, and very sparse blebs of galena occur in fractures in the quartz and shale.
DEVELOPMENT: Two small pits
SAMPLING: Two chip samples of fractured country rock with sulfides contained as much as a trace of gold, 0.3 troy oz of silver per ton (10.3 g/t), 0.016 percent zinc, and 0.006 percent lead.
CONCLUSIONS: Low metallic content indicates no mineral-resource potential.

NAME: Prospect C
INDEX MAP NO.: Fig. 38
LOCATION: About 2,000 ft (600 m) north from Koip Peak
ELEVATION: 12,300 ft (3,750 m)
ACCESS: By trail 6 mi (10 km) southeast from Tioga Pass road
GEOLOGY OF DEPOSIT: The prospect is underlain by thin-bedded siliceous limestone. Gray quartzite with relict bedding strikes N. 44° W. and dips 85° SW. Widely scattered quartz stringers, 0.25 to 0.5 in. (0.65-1.27 cm) thick, parallel the bedding. The quartz stringers contain disseminated pyrite and sparsely distributed galena.
DEVELOPMENT: One adit, 8 ft (2.4 m) long, one open cut about 20 ft (6.1 m) into the hillside and no more than 3 ft (0.9 m) wide, and one small cut
SAMPLING: Four samples assayed as much as a trace of gold, 8.2 troy oz of silver per ton (260 g/t), 3.7 percent lead, and 1.7 percent zinc.
CONCLUSIONS: A small resource potential for silver, lead, and zinc may exist.

NAME: Prospect D
INDEX MAP NO.: Fig. 38
LOCATION: About 3,500 ft (1,070 m) northwest of Parker Peak
ELEVATION: 11,400 ft (3,470 m)
ACCESS: By trail 6.5 mi (10.5 km) southeast from Tioga Pass road
GEOLOGY OF DEPOSIT: Quartzite, 100 to 150 ft (30-46 m) thick,

with relict bedding striking N. 70° W. and dipping vertically. In places, the quartzite contains abundant pyrite and hematite.
DEVELOPMENT: One 4- by 4-ft (1.2 by 1.2 m) shaft 41 ft (12.5 m) deep
SAMPLING: One select and one grab sample were taken. The select sample of pyrite-rich quartzite contained a trace of gold, 7.5 troy oz of silver per ton (230 g/t), no copper or molybdenum, and less than 0.02 percent WO_3. The grab sample had no significant metallic content.
CONCLUSIONS: Sample analyses indicate no resource potential.

NAME: Prospect E
INDEX MAP NO.: Fig. 38
LOCATION: About 1,300 ft (400 m) northwest of Parker Peak
ELEVATION: 12,400 ft (3,780 m)
ACCESS: By trail 7 mi (11 km) southeast from Tioga Pass road
GEOLOGY OF DEPOSIT: Country rock is sheared quartzite, which on the surface weathers to brown, and siliceous shale of medium-gray color. Quartz occurs as a fracture filling with no visible metallic minerals.
DEVELOPMENT: Two small pits
SAMPLING: Two grab samples from the pit dumps contained no gold and only traces of silver.
CONCLUSIONS: No resource potential.

NAME: Queen of the West prospect
INDEX MAP NO.: Fig. 35
LOCATION: Along Alger Creek, 2,800 ft (850 m) southeast of lower Alger Lake
ELEVATION: 10,300 ft (3,140 m)
ACCESS: By trail 7 mi (11 km) northwest from Silver Lake
HISTORY: Apparently, development was before the turn of the 20th century.
GEOLOGY OF DEPOSIT: The prospect is near a contact between metaquartz-rhyolite containing stretched quartz clasts and vesicles and iron-oxide-stained quartzofeldspathic hornfels. Hydrothermal solutions were introduced along joints and fractures and bedding planes in metamorphosed rocks. No metallic minerals are visible.
DEVELOPMENT: A 22-ft (6.7 m)-deep shaft
SAMPLING: Two grab samples from the shaft dump had no detectable gold or silver.
CONCLUSIONS: The prospect has no mineral-resource potential.

NAME: Red Bank prospect
INDEX MAP NO.: Fig. 37
LOCATION: West of Lake Catherine about 1 mi (1.6 km)
ELEVATION: About 10,700 ft (3,260 m)
ACCESS: By trail 15 mi (24 km) northeast from Clover Meadow
GEOLOGY OF DEPOSIT: A rusty-weathered altered irregular mass of metavolcanic rock crops out across a ridge. The rocks trend northwest, dip nearly vertically, and are at least 1,000 ft (300 m) thick and 2,000 ft (600 m) long. They contain as much as 5 percent very fine grained disseminated sulfide blebs, mostly pyrite. Quartz, epidote, and chlorite are major constituents.
DEVELOPMENT: No workings
SAMPLING: A total of 21 samples of altered metavolcanic rocks had at maximum a trace of gold, 0.3 troy oz of silver per ton (10 g/t), 0.01 percent copper, 0.038 percent lead, and 0.11 percent zinc.
CONCLUSIONS: No resource potential

NAME: Red Top Mountain prospects
INDEX MAP NO.: Fig. 33, No. 11
LOCATION: On the northeast slope of Red Top Mountain
ELEVATION: Workings are between 8,900 and 10,300 ft (2,710 and 3,140 m)
ACCESS: By trail 5 mi (8 km) northwest from Devils Postpile National Monument
HISTORY: Prospects are on claims staked before the turn of the 20th century. The latest claim-locating activity was in 1935.
GEOLOGY OF DEPOSIT: Numerous structures were formed in the granodiorite of Lost Dog Lake subsequent to intrusion of quartz monzonite (Chapter A, this volume). These structures include shear zones, joints, and fractures with various attitudes. Aplite dikes and quartz veins with sulfides occur along the structures. Randomly occurring sulfides are, in decreasing amounts, pyrite, chalcopyrite, and molybdenite. Pyrite is also disseminated in the granodiorite.
DEVELOPMENT: One caved adit, six trenches, and seven prospect pits (fig. 55)
SAMPLING: A total of 34 samples were taken from the prospects. Sample localities are shown on figure 55, with corresponding analyses in table 28. The samples contained as much as a trace of gold, 0.2 troy oz of silver per ton (6.9 g/t), 0.048 percent copper, 0.35 percent molybdenum, and 0.54 percent WO_3.
CONCLUSIONS: No mineral-resource potential exists in exposed structures, although additional exploration, including diamond drilling, may reveal a low-grade copper-molybdenum deposit at depth.

TABLE 28.—*Analytical data for Red Top Mountain prospects*

[Sample locations shown on figure 55. Tr, trace; N, not detected; N.d., not determined; <, less than shown]

Sample				Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Copper (percent)	Molybdenum (percent)	Tungsten oxide (WO_3) (percent)
No.	Type	Length (feet)[1]	Description					
1	Grab	--	From granodiorite	N	N	0.004	N.d.	N.d.
2	Select	--	From granodiorite with a trace of pyrite	N	N	.003	N.d.	N.d.
3	Grab	--	From granodiorite with milky quartz and pyrite	N	N	.009	N.d.	N.d.
4	Select	--	From granodiorite with pyrite	N	N	.005	N.d.	N.d.
5	Grab	--	From iron-oxide-stained granodiorite with about 2 percent pyrite	N	N	.011	.13	0.35
6	Select	--	do	N	N	.009	.27	.54
7	Grab	--	From granodiorite	N	N	.003	N.d.	N.d.
8	do	--	From granodiorite with 5 percent pyrite	Tr	.20	.012	N.d.	N.d.
9	Select	--	From granodiorite with 5 percent pyrite	Tr	N	.020	N.d.	N.d.
10	Grab	--	From granodiorite	N	.10	.017	N.d.	N.d.
11	Select	--	From granodiorite with 1 percent pyrite	N	N	.019	N.d.	N.d.
12	do	--	From iron-oxide-stained schistose aplite	N	N	.005	N.d.	N.d.

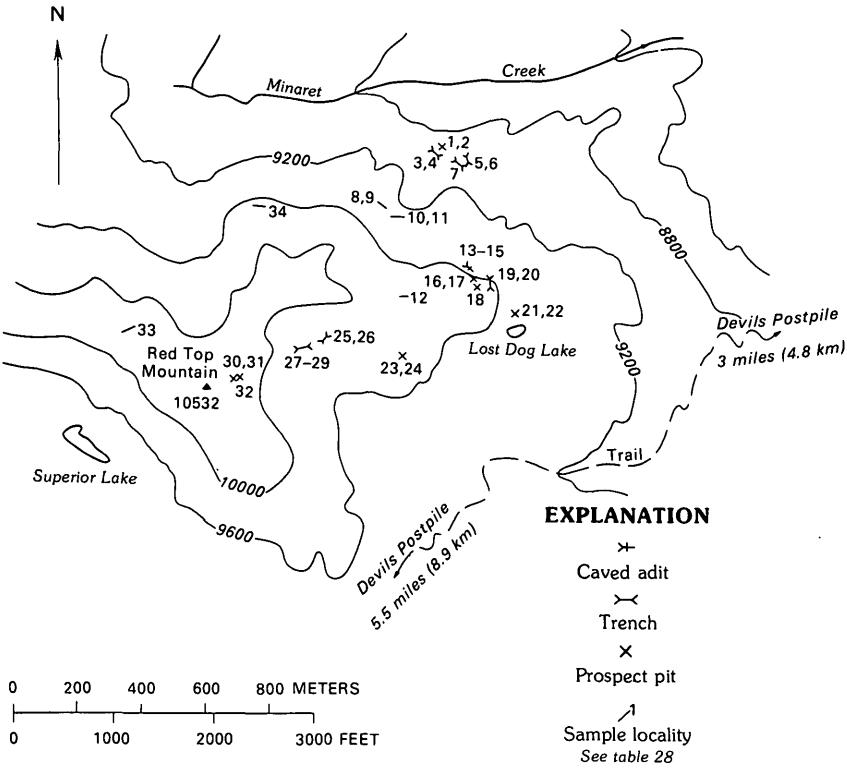


FIGURE 55.—Red Top Mountain prospects. Contours in feet.

TABLE 28.—*Analytical data for Red Top Mountain prospects*—Continued

Sample No.	Type	Length (feet)[1]	Description	Gold (troy oz per ton)[1]	Silver (troy oz per ton)[1]	Copper (percent)	Molybdenum (percent)	Tungsten (WO_3) (percent)
13	Chip	2.0	Across shear zone composed of gouge, greenish-gray schist, and granodiorite	N	N	0.025	0.15	0.05
14	Grab	--	do	N	N	.013	.20	N.d.
15	Select	--	do	N	.10	.023	N.d.	N.d.
16	Grab	--	From milky-quartz float containing pyrite, chalcopyrite, magnetite, and iron oxides	N	N	.031	.33	.16
17	Select	--	do	N	N	.008	.35	.26
18	do	--	From schist and granodiorite with a trace of pyrite	N	N	.046	.008	<.01
19	Grab	--	From milky-quartz vein in granodiorite containing 1 percent pyrite, 0.5 percent chalcopyrite, and 0.5 percent molybdenite	N	N	.007	.27	.06
20	Select	--	do	N	N	.006	.22	.14
21	Grab	--	From aplite with minor amounts of pyrite	N	N	.003	N.d.	.01
22	do	--	From granodiorite with very minor amounts of molybdenite	N	N	.012	.066	N.d.
23	Select	--	do	Tr	.20	.008	.094	.24
24	Grab	--	From iron-oxide-stained schistose aplite	N	N	.005	N.d.	N.d.
25	do	--	From alpite containing 5 percent pyrite and 0.5 percent chalcopyrite	N	N	.014	N.d.	<.01
26	Select	--	do	N	N	.029	N.d.	.04
27	Chip	10.5	From across schistose aplite containing 1 percent pyrite, 0.5 percent magnetite, and 0.5 percent limonite	N	N	.027	N.d.	.16
28	Grab	--	do	N	N	.030	N.d.	.36
29	Select	--	do	N	N	.048	N.d.	.17
30	Grab	--	From granodiorite containing 5 percent pyrite	Tr	.20	.017	N.d.	N.d.
31	Select	--	do	N	.10	.017	N.d.	N.d.
32	Chip	48.0	Across aplite dike containing pyrite	N	N	.018	N.d.	N.d.
33	Grab	--	From aplite with abundant pyrite	N	N	.009	N.d.	N.d.
34	do	--	do	N	N	.037	N.d.	N.d.

[1]Metric conversions: feet × 0.3048 = meters; troy ounces per ton × 34.285 = grams per tonne.

NAME: Shadow Lake prospect
INDEX MAP NO.: Fig. 36
LOCATION: North and south of lower Shadow Creek
ELEVATION: 8,300 to 8,900 ft (2,530 to 2,710 m)
ACCESS: By trail 3 mi (5 km) northwest from Agnew Meadows
HISTORY: Claims were originally staked in the area in 1905 by J. R. Morton and F. H. Paatsch.
GEOLOGY OF DEPOSIT: The area is underlain by a sequence of

metamorphosed volcanic and sedimentary rocks. Metavolcanic tuff and flows predominate, with lesser amounts of quartz-biotite schist, volcanic breccia, and calcareous sedimentary rocks. The rocks trend N. 35°-40° W. with near-vertical dips. Small unmineralized tactite zones are near volcanic-sedimentary rock contacts. Quartz veins with no sulfides are scattered throughout the rocks.

DEVELOPMENT: No evidence of claim location or exploration activity was found.

SAMPLING: Twelve chip samples were taken across outcrops. Five were from across quartz veins and stringers, three across small tactite zones, and four across metamorphosed volcanic rocks. Samples contained as much as 0.02 troy oz of gold per ton (0.69 g/t) and 0.8 troy oz of silver per ton (27.4 g/t), with insignificant amounts of other metals.

CONCLUSIONS: Sample analyses indicate no resource potential.

NAME: Sheep Crossing prospect

INDEX MAP NO.: Fig. 33, No. 13

LOCATION: About 2 mi (3 km) southeast of Green Mountain, north about 0.5 mi (0.8 km) from the bridge across the North Fork San Joaquin River

ELEVATION: About 6,000 ft (1,800 m)

ACCESS: By trail approximately 4.5 mi (7.2 km) from Clover Meadow

GEOLOGY OF DEPOSIT: Quartz-feldspar pegmatite bodies crop out in the Mount Givens Granodiorite. The bodies, about 10 ft (3 m) apart, are 3.5 and 4.5 ft (1.1 and 1.4 m) wide and less than 70 ft (20 m) long. Magnetite-rich pods, as much as 1 to 5 ft (0.3–1.5 m) thick, make up less than 0.5 percent of the lenses.

SAMPLING: Three samples, including the magnetite-rich pods, contained a maximum of 0.2 troy oz of silver per ton (6.9 g/t), 0.01 percent copper, and 0.02 percent zinc.

CONCLUSIONS: No resource potential is indicated.

NAME: Silver King prospect

INDEX MAP NO.: Fig. 37

LOCATION: About 1 mi (1.6 km) east of the southern part of Twin Island Lake

ELEVATION: About 9,600 ft (2,930 m)

ACCESS: By trail 14 mi (22 km) northeast from Clover Meadow

HISTORY: B. P. Kenady and J. Chubb located the prospect in 1953.

GEOLOGY OF DEPOSIT: Mineralized shear zones trend N. 40°-88° W. and dip 30° NE. to vertically in silicified metavolcanic rocks and fine-grained intrusive felsic rocks. The shear zones are composed mainly of wallrock slices, quartz, and sulfides. The zones, as much as 15 ft (4.6 m) thick and 150 ft (46 m) long, contain about 10 percent sulfides. The sulfides, chalcopyrite, galena, sphalerite, and pyrite occur in masses from 1 to 6 in. (2.5–15 cm) thick.

DEVELOPMENT: Five pits and trenches, each less than 30 ft (9.1 m) long and 10 ft (3 m) deep

SAMPLING: Ten samples contained traces of gold, 12.7 troy oz of silver per ton (435 g/t), 0.064 percent copper, 9.2 percent lead, and 16 percent zinc.

CONCLUSIONS: A small subeconomic resource potential exists.

NAME: Snowflower claim

INDEX MAP NO.: Fig. 37

LOCATION: About 0.5 mi (0.8 km) north of the northern part of Twin Island Lake

ELEVATION: About 9,800 ft (3,000 m)

ACCESS: By trail 15 mi (24 km) northeast from Clover Meadow

HISTORY: Ed J. Roberts, Lou R. Johnston, Lou R. Johnston, Jr., H. M. Bliss, and Taylor F. Johnson located the claim on June 13, 1926. On August 24, 1936, D. A. Miner, Ira Bender, and O. J. Lyons left location notices on the west end of the claim, which they called the Mohawk.

GEOLOGY OF DEPOSIT: A nearly vertically dipping shear zone that strikes about N. 75° W. is filled by an andesitic dike. Country rocks are metamorphosed volcanic rocks. The dike fills 85 to 100 percent of the shear zone, which is 5 to 20 ft (1.5-6.1 m) thick. Scattered sulfide blebs and masses, mostly pyrite, are along the contacts of the dike.

SAMPLING: Eleven samples contained as much as a trace of gold and 0.3 troy oz of silver per ton (10 g/t).

CONCLUSIONS: No resource potential is indicated.

NAME: Stevenson Meadow prospect

INDEX MAP NO.: Fig. 33, No. 8

LOCATION: Along the North Fork San Joaquin River, downstream from the mouth of Bench Creek

ELEVATION: About 8,300 ft (2,500 m)

ACCESS: By trail 12 mi (19 km) north from Clover Meadow

GEOLOGY OF DEPOSIT: Iron-oxide-stained metavolcanic and metasedimentary rocks, diorite and gabbro, micaceous schist, and a lens of pyrophyllite-bearing rocks underlie the prospect.

Some rocks have been metamorphosed to hornfels. Major structures, including isoclinal folds and shears, trend N. 50° W. to north-south and dip westerly. The pyrophyllite-bearing lens is about 700 ft (210 m) thick and at least 2,700 ft (825 m) long, splitting and thinning at its ends. It is composed of about 15 percent pyrophyllite, in layers 5 to 25 ft (1.5–7.1 m) thick, alternating with layers of talc and chlorite. The lens contains less than 2 percent pyrite on blebs and is locally coated by azurite and malachite. Quartzose masses, mainly in the pyrophyllitic lens but also in other rock types, make up about 10 percent of the outcrops. Lazulite, some of lapidary quality, is disseminated as small crystals and blebs in the quartzose masses. Fluorite, tourmaline, and rutile are minor accessory minerals in the masses.

SAMPLING: A total of 36 samples were taken of all rock types. They assayed as much as 0.01 ounce gold per ton (3.4 g/t), 0.2 troy oz of silver per ton (6.9 g/t), and 0.19 percent copper, although most analyses were less than 0.01 percent copper.

CONCLUSIONS: No resource potential is indicated.

NAME: Tom Agnew group prospects

INDEX MAP NO.: Fig. 36

LOCATION: At the Wilderness boundary on the high trail northwest of Agnew Meadows

ELEVATION: 9,600 ft (2,930 m)

ACCESS: By trail 2.5 mi (4 km) northwest from Agnew Meadows

HISTORY: The prospects are on claims originally staked by Tom Agnew in 1878. Since then, they have been restaked many times by other prospectors.

GEOLOGY OF DEPOSIT: Discontinuous quartz veins occur as fracture fillings in northwest-trending beds of siliceous hornfels in dark (graphitic?) phyllite. The veins are mainly in east-west-trending crossfractures, typically less than 30 ft (9 m) long and ranging from less than 1 in. to 1.5 ft (2–45 cm) thick. Sparse metallic sulfides in the veins include pyrite, galena, sphalerite, and possibly argentite.

DEVELOPMENT: Two prospect pits and a shallow shaft

SAMPLING: Six chip and two grab samples were taken from the workings. Sample analyses ranged from 0.1 to 16 troy oz of silver per ton (34–550 g/t), as much as 0.66 percent lead, and 0.06 troy oz of gold per ton (2.1 g/t).

CONCLUSIONS: Assays indicate a small resource potential for silver.

NAME: Vera Mae claims
INDEX MAP NO.: Fig. 39
LOCATION: Near the head of North Fork Iron Creek
ELEVATION: 10,200 ft (3,100 m)
ACCESS: By trail northeast about 14 mi (22 km) from Clover Meadow
HISTORY: The Vera Mae Nos. 4 and 5 claims were located in 1915 by S. H. Colburns. They were surveyed for patent in September 1916; later, a patent was issued.
GEOLOGY OF DEPOSIT: A quartz vein-striking N. 6°-10° W. and dipping 44°-80° NE., is in fine-grained to porphyritic granitic rock of the Shellenbarger Lake pluton. The vein ranges from 1.3 to 4.9 ft (0.4-1.5 m) in thickness, with segments traceable on the surface for 2,200 ft (670 m). Wolframite occurs in isolated and widely scattered blebs and very short stringers within the vein. An ultraviolet lamp indicates that scheelite occurs in the wolframite in masses as much as ⅛ in. (0.3 cm) across. Lesser amounts of chalcopyrite are present, commonly near the blebs of wolframite.
DEVELOPMENT: Three small prospect pits
SAMPLING: Four chip and two grab samples of quartz vein material were taken. The grab samples had as much as a trace gold, 0.5 troy oz of silver per ton (17 g/t), and 1.35 percent WO_3. One chip sample contained 0.41 percent WO_3, but analyses of other samples had no significant metallic content.
CONCLUSIONS: The quartz vein is continuous, but the metallic minerals are widely scattered. No resource potential is indicated.

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