MINERAL RESOURCE POTENTIAL OF THE JOHN MUIR WILDERNESS, FRESNO, INYO, MADERA, AND MONO COUNTIES, CALIFORNIA

SUMMARY REPORT

By

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STUDIES RELATED TO WILDERNESS

Under the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and the Joint Conference Report on Senate Bill 4, 88th Congress, the U.S. Geological Survey and the U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System, and some of them are presently being studied. The act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. The act directs that the results of such surveys are to be made available to the public and be submitted to the President and the Congress. This report discusses the results of a mineral survey of the John Muir Wilderness, Inyo and Sierra National Forests, Fresno, Inyo, Madera, and Mono Counties, California. The area was established as a wilderness by Public Law 88-577, September 3, 1964.

SUMMARY

The U.S. Bureau of Mines and the U.S. Geological Survey identified many areas of the John Muir Wilderness as having marginal and subeconomic resources[3] of tungsten, molybdenum, copper, gold, and silver. Geologic, geochemical, and geophysical evidence suggests that undiscovered deposits may also exist within the wilderness. Tungsten is the principal metallic commodity in the area, and with accompanying resources of gold, copper, silver, and molybdenum, is found along contacts between granitic rocks and metamorphosed calcareous sedimentary rocks in the Pine Creek and Mount Morrison roof pendants[4] and in many smaller septa[4] located elsewhere. Gold and silver resources in the wilderness are present around Kearsarge Peak, 2 miles northeast of Kearsarge Pass, and along Hilton Creek; marginal resources of silver, copper, lead, and zinc exist along Hilton Creek. A small subeconomic resource of uranium may exist near the northwest boundary of the wilderness. Small cobalt resources occur near the head of Bishop Creek. Stone, sand, and gravel are abundant, but such material is available closer to markets. This study revealed no known potential for coal, oil, gas, or geothermal resources. The north boundary of the wilderness adjoins the south edge of the Mono-Long Valley "Known Geothermal Resource Area" (KGRA); however, the greatest geothermal potential is associated with Quaternary volcanic rocks which do not extend into the study area. A single hot spring exists within the wilderness, but the rock type indicates a local source not associated with the KGRA heat source. Along the west side of the Pine Creek pendant, adjacent to the wilderness, are tactite zones forming the largest, most productive tungsten reserves in the United States.

The evident association of metallic mineral deposits with metasedimentary and metavolcanic rocks in roof pendants and septa of the wilderness suggests that additional exploration might reveal undiscovered resources of tungsten, copper, molybdenum, silver, and gold. Further exploration in areas where metallic minerals occur along fractures and shear zones in the granitic rocks might result in additional discoveries of copper and molybdenum.

Areas of the wilderness designated as having mineral resource potential were chosen on the basis of the presence of (1) known mineral occurrences, (2) favorable host rocks, (3) drainage basins with groups of geochemically anomalous samples, and (4) aeromagnetic anomalies. Areas with exposed calcareous metasedimentary rocks were automatically considered favorable for tactite-type deposits, for these deposits occur in many calcareous metasedimentary units, which are the most common setting of economic mineral deposits in the Sierra Nevada. Degrees of resource favorability were assigned on the basis of presence or absence of known deposits and the presence and degree of geochemical anomalies. Some areas were designated as having mineral potential on the basis of geochemical anomalies alone; these areas are considered to have low favorability for mineral deposits. Individual areas with potential for undiscovered resources are discussed below.

INTRODUCTION

The John Muir Wilderness covers 483,155 acres (195,533 ha) in the rugged southern part of the Sierra Nevada fig. 1). The area is bounded on the east by the Owens Valley and on the west by other U.S. Forest Service lands and Kings Canyon and Sequoia National Parks. The east side of the area is accessible from U.S. Highway 395; access from the west is by state, county, and Forest Service roads from the San Joaquin Valley.

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[1]U.S. Geological Survey

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[3]The word "resource" is used here as defined by the U.S. Bureau of Mines and U.S. Geological Survey (1980): "A concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible."

[4]"Pendant" or "roof pendant", as used here, means a downward projecting body of metamorphic rock, of varied shape, in a plutonic body. It is presumed to be a remnant of the roof of country rock into which the plutonic rock intruded. Many pendants separate two plutonic bodies; such a pendant that is thin and markedly elongate in outcrop is called a "septum". "Septum" (pl. "septa"), as used here, means a thin and commonly discontinuous belt of metamorphic rock at a contact between two plutonic bodies.

A generalized geologic map of the John Muir Wilderness was compiled by du Bray (1981). That map and larger scale geologic maps by Bateman (1956, 1965a, b), Bateman and Moore (1965), Bateman and others (1971), Huber and Rinehart (1965), Lockwood (1975), Lockwood and Lydon (1975), Moore (1963, 1981), and Rinehart and Ross (1957, 1964) outline geologic settings of mining districts, mines, and prospects and delineate pendants of metamorphic rocks which contain most of the mineral resources. Other publications pertinent to the mineral potential of the wilderness include Lockwood and others (1972), Mayo (1934), and Moore and Marks (1972).

Mining in the John Muir Wilderness began about 1864 in the Kearsarge district, but most mines were closed by 1870. The district yielded both gold and silver. The Mammoth district, located within the Mount Morrison roof pendant, yielded gold and silver from 1878 through the early 1900's.

In 1916, tungsten was discovered in the Pine Creek pendant area. The first recorded production, in 1918, was from the Pine Creek mine, adjacent to the northeast boundary of the wilderness. The Pine Creek mine is currently the largest tungsten producer in the United States.

GEOLOGY PERTAINING TO THE MINERAL RESOURCE ASSESSMENT

The John Muir Wilderness is principally underlain by granitic plutons of the Sierra Nevada batholith, but metamorphic rocks and Cenozoic volcanic rocks underlie about 20 percent of the area. Radiometric dating indicates that most of the plutons are of Cretaceous age, but some are as old as Triassic (Evernden and Kistler, 1970; Chen, 1977; Stern and others, 1981). Most of the plutonic rocks are felsic, but small bodies of diorite and gabbro[5] are also present. The composition of the metavolcanic rocks ranges from basaltic to rhyolitic; the metasedimentary units are primarily quartzite and calc-silicate rocks.

The metamorphic rocks are of particular interest because they are potential hosts to metallic ore deposits. Metamorphism, which took place during emplacement of the Sierra Nevada batholith, was primarily thermal and occurred at albite-epidote to hornblende-hornfels facies conditions. The metamorphic rocks are usually well stratified and foliated. Areas dominated by metamorphic rocks include the Mount Morrison pendant in the Mount Morrison, Mount Abbot, and Devils Postpile quadrangles (area A on fig. 2); the Pine Creek pendant (area B) and the Mount Humphreys septum (area F) in the Mount Tom quadrangle; the Oak Creek pendant (area M) in the Mount Pinchot quadrangle; and the Goddard pendant in the Blackcap Mountain and Mount Goddard quadrangles. Small masses of metamorphic rocks occur throughout the wilderness.

The rocks of the Mount Morrison pendant are chiefly metasedimentary rocks of early and late Paleozoic age. The protoliths of these rocks were marine clastic and carbonate sediments that formed the west margin of the Paleozoic North American continent. The bulk of the stratigraphic section is composed of dark quartz-rich hornfels; other common rock types include marble, pelitic hornfels, calc-silicate rocks, and quartzite (Rinehart and Ross, 1964). Marble adjacent to plutonic contacts has commonly been converted to pods and stringers of tactite. Resources of tungsten, with accompanying gold, silver, copper, and molybdenum, occur in these small bodies. Most of the calcareous metasedimentary rocks in the wilderness are found in the Pine Creek and Mount Morrison pendants; other tactite deposits, some with known tungsten production, also occur in small septa located elsewhere in the wilderness, mostly on the east side of the Sierra Nevada crest. The Mount Morrison and Pine Creek pendants are assigned a high geologic favorability for tungsten deposits; the upper Big Pine Creek, Mount Humphreys, Mount Pinchot, and Lookout Point areas (E, F, K, and L, fig. 2) have moderate geologic favorability for tactite deposits and associated tungsten resources.

Metavolcanic rocks are common throughout the wilderness, especially in the Goddard and Oak Creek pendants and in the west limb of the Mount Morrison pendant (area D). Most of the metamorphic rocks in the southern part of the wilderness are metavolcanic. Extrusion of these rocks, which are predominately silicic, probably coincided with the onset of subduction and formation of an Andean-type arc complex at the Mesozoic continental margin. Fine-grained metarhyolite, metadacite, meta-andesite, and metabasalt are all common and form flows, tuffs, and volcanic breccia. The basalts usually occur as massive flows, whereas the silicic volcanic rocks are found in bedded deposits. Gold and silver were mined from vein deposits in altered metavolcanic rocks in the west limb of the Mount Morrison pendant, just outside the wilderness; this altered zone extends into the wilderness (area D, fig. 2). The Kearsarge district gold-silver mines are associated with the Oak Creek metavolcanic pendant (area M). Areas D and M have moderate geologic favorability for undiscovered gold-silver deposits.

About 50 discrete, separately emplaced plutons crop out in the wilderness. A complete range of composition between alaskitic granite and hornblende gabbro is represented. Four principal granitic types are most common. The most distinguishable of these is the granodiorite of Cathedral Peak type; two very large plutons are characterized by zoned potassium feldspar megacrysts as much as 2 in. (5 cm) long set in a coarse-grained matrix of quartz, feldspar, and biotite. These plutons straddle the granite-granodiorite compositional boundary, have a color index between 6 and 12, and contain biotite as the principal mafic mineral. Nine alaskitic granites crop out in the wilderness. These plutons are medium grained, contain roughly equal amounts of quartz, potassium feldspar, and plagioclase and contain less than 5 percent mafic minerals, principally biotite. Nonalaskitic granite crops out in 14 plutons in which potassium feldspar accounts for more than one-third of all feldspar, quartz content is greater than 20 percent, color index ranges between 5 and 15, and megacrysts characteristic of the Cathedral Peak-type granodiorite are absent; hornblende and biotite are the principal mafic minerals. Granodiorite is the last common granitic type. The 25 granodioritic plutons are medium- to fine-grained bodies that contain hornblende as the principal mafic mineral, have color indices between 10 and 25, contain numerous mafic inclusions, and commonly contain accessory sphene.

Five percent of the John Muir Wilderness area is underlain by Cenozoic volcanic rocks. These are primarily basalt flows; they are found in the Sawmill Creek (northeast of Sawmill Pass) and Taboose Creek drainages, around Pincushion Peak in the Kaiser Peak quadrangle, at the southern border of the Blackcap Mountain quadrangle, throughout the Tehipite Dome quadrangle, and south of Devils Postpile. A small body of rhyolite tuff occurs south of Devils Postpile.

The present landform of the John Muir Wilderness is primarily the result of rapid uplift, volcanism, and glaciation. Uplift and westward tilting of the Sierra Nevada block resulted in rapid erosion of the roof rock and exposure of the batholith. Parts of the wilderness were subsequently covered by volcanic flows and cinder accumulations. Glaciation in Pleistocene time left the range with its present form. Uplift of the Sierra Nevada is still occurring along faults on the eastern range front.

GEOCHEMISTRY PERTAINING TO THE MINERAL RESOURCE ASSESSMENT

A geochemical survey of the John Muir Wilderness was conducted by the U.S. Geological Survey between 1969 and 1978. Stream-sediment samples were collected at 1,434 sites

[5]Plutonic rock nomenclature used herein is that of Streckeisen (1973).

in the wilderness and immediately adjacent areas. Analytical data for these samples and a map of sample localities are presented by du Bray and Dellinger (1980) and Diggles and others (1981). Geochemical anomaly maps, anomaly interpretations, and descriptions of sampling methods, analytical techniques, and data reduction procedures are contained in Dellinger and others (1982).

The results of the geochemical survey indicate that significant mineralization occurs primarily in metasomatic deposits at contacts between granitic and calc-silicate rocks, in silicified and (or) chloritized joints in granitic rocks, and in altered metavolcanic rocks. All of the mines and prospects in or near the wilderness are associated with one of these features. Many of the geochemical anomalies are apparently related to mineralization, but the geochemical survey did not reveal any large undiscovered deposits. Neither the extremely high values nor the extensive lateral persistence of stream-sediment anomalies, usually associated with large deposits, were observed.

Tungsten, the element most likely to be found in economic deposits in the study area, occurs as scheelite ($CaWO_4$) in thin bands of tactite at contacts between granitic and calc-silicate rocks. Tungsten was detected in very few samples; even in some samples collected downstream from known deposits (e.g., the Hard Point and Tungstar mines, loc. 4, 15), it was not detected. The very low ratio of the size of any mineralized area to the size of the area drained at a typical sampling site accounts for the low tungsten concentrations. In addition, because minerals containing tungsten tend to concentrate in pockets of heavy minerals in stream beds, random stream-sediment samples are unlikely to contain tungsten-bearing material. For these reasons, neither the sensitivity of the analytical methods nor the sampling-site density were sufficient to detect tactite deposits. The geochemical survey, therefore, provided very little information about the presence or absence of tungsten deposits. Further exploration using higher sampling-site density, the analysis of heavy-mineral concentrates, and analytical techniques capable of measuring smaller concentrations might detect additional deposits.

Recognition of low-level anomalies in samples from some parts of the wilderness resulted from the use of quantitative analytical techniques. The lower detection limits of semiquantitative emission spectrography for zinc, silver, tungsten, tin, gold, and arsenic are above the natural anomaly-threshold values of the sample population; samples with anomalous concentration below the lower detection limits for these elements cannot, therefore, be recognized using this analytical technique. Analyses by atomic absorption spectrophotometry, colorimetry, or a combined fire-assay and atomic-absorption technique were done for zinc, gold, arsenic, copper, and tungsten on samples from some areas of the wilderness. The sensitivity of these quantitative methods is considerably greater than that of semiquantitative spectrography; anomalous samples with concentrations between the lower detection limits of these methods and those of semiquantitative emission spectrography are therefore detected. Most of the more sensitive analyses were done on samples from the northwestern part of the wilderness; area G (fig. 2) was recognized largely on the basis of more sensitive analytical techniques used only there.

GEOPHYSICS PERTAINING TO THE MINERAL RESOURCE ASSESSMENT

An aeromagnetic survey of the study area was flown along east-west lines spaced approximately 1 mi (1.6 km) apart at an elevation of 13,500 ft (4,100 m) in the northern part and 14,000 ft (4,300 m) in the southern part. Lower level surveys at 1,000 ft (300 m) of terrain clearance were flown in two western parts of the study area where most of the terrain is less than 9,000 ft (2,700 m) in elevation. These surveys were made because anomalies associated with possible mineral deposits would not have been recognizable from the higher-level survey (H. W. Oliver, unpub. data, 1982).

Most of the magnetic anomalies are associated with topography or are consistent with the magnetic properties of the rocks exposed at the surface. The largest magnetic highs are associated with mafic plutonic rock, which generally contains several percent finely disseminated magnetite. Moderately high magnetic anomalies also occur over mafic metavolcanic rocks in the Mount Morrison and Goddard roof pendants, but these are not nearly as large as the 600-gamma high, at 3,300 ft (1,000 m) above the metavolcanic rocks of Iron Mountain, which locates a significant magnetite deposit about 5 mi (8 km) northwest of the north boundary of the wilderness (Oliver, 1982). Magnetic lows are associated with the most felsic granitic rocks (alaskites and Cathedral Peak type) as well as the metasedimentary rocks, particularly the marbles in the roof pendants. Extensive magnetic lows over intermediate to mafic plutonic rocks often indicate mineralized zones, but none were revealed by the survey.

A comparison of magnetic anomalies with the geochemical anomalies reported by Dellinger and others (1982) indicates that magnetic highs are associated with many of the nickel and chromium anomalies and a few of the copper and silver anomalies. A magnetic low 2.5 mi (4 km) west of Florence Lake is associated with a tungsten and molybdenum anomaly. Magnetic lineaments over alternating metavolcanic and metasedimentary rocks on the west limb of the Mount Morrison pendant reflect the structure of the pendant and a concordant zone of silver-gold-zinc mineralization.

The magnetic data show that (1) there are no large deposits of magnetite or pyrrhotite comparable to the Iron Mountain deposit, (2) there are no buried masses of magnetite-rich serpentinite within the wilderness area, such as those that contain gold and silver in the Sierra Nevada foothills, and (3) there are several nickel and chromium geochemical anomalies, substantiated by large magnetic highs, associated with mafic plutonic rocks. No major mineralized areas were revealed by the magnetic data.

MINING DISTRICTS AND MINERALIZATION

Most of the mineral deposits in the wilderness are associated with roof pendants; outlying claims and scattered metallic ore deposits in granitic rocks also occur. The first recorded systematic mining in the wilderness was underway on the south side of Kearsarge Peak by 1865; however, grade and continuity of ore were insufficient to sustain profitable operations, and most mines in the district closed by 1870. The Rex Montis mine on the north side of Kearsarge Peak was developed and operated mainly between 1875 and 1883. Kearsarge district mines, principally the Rex Montis, produced nearly 12,400 oz (386,000 g) of combined gold and silver before 1900.

The Mammoth district, on the northwest side of the wilderness, was the site of the first mining activity in the Mount Morrison pendant. Gold and silver valued at more than $1 million were produced from the district between 1878 and the early 1900's. Production from the major tungsten mines (Hard Point, Scheelore, Phelps Hilton Creek, and Nicoll Hilton Creek) in the pendant was in excess of 46,800 short ton units (stu)[6] (425,000 kg) of tungsten trioxide (WO_3).

In 1916 tungsten was discovered at several places within the Pine Creek pendant, which is situated along the northeast wilderness boundary; the first recorded production, in 1918, was from the Pine Creek mine, adjacent to the wilderness. Mining was sporadic from 1918 to 1936 because

[6] A short ton unit, abbreviated stu, equals 1 percent of a short ton or 20 lb (9.072 kg) of WO_3, or 15.862 lb (7.195 kg) of tungsten (W), and is used to report tungsten assay values and to express market value of ore or concentrates.

of fluctuating tungsten prices. The U.S. Vanadium Corporation purchased the Pine Creek mine in 1936 and began major development and production. In 1937, tungsten ore was discovered at the Tungstar mine, and production commenced in 1939. The Pine Creek mine, now owned and operated by Union Carbide Corporation, is the largest tungsten producer in the United States.

Production from mines adjacent to the wilderness in the Pine Creek pendant area, principally from Union Carbide Corporation mines at Pine Creek, has been 4.5 to 5.0 million stu (41 to 45 million kg) WO_3; 5.5 million lb (2.5 million kg) copper; 7.0 million lb (3.2 million kg) molybdenum; and 1.0 million troy ounces (56 million g) silver. Although gold production from the Cardinal mine on Bishop Creek has been more than 45,000 troy oz (1.4 million g), recorded gold production from the Pine Creek mine has been small, totaling about 4,700 troy oz (146,200 g). Production from within the wilderness in the Pine Creek pendant area totals nearly 143,000 stu (1.30 million kg) WO_3.

Records from Fresno, Madera, Inyo, and Mono Counties show that as many as 1,770 lode claims may have been staked in the wilderness; 12 claims are patented. No placer claims were identified.

The metallic mineral resources of the wilderness occur in only a few geologically distinct environments. Tungsten, predominantly in scheelite, occurs within garnet-epidote tactite along contact zones between calcareous metasedimentary rocks and granitic intrusive rocks. Scheelite is commonly accompanied by copper and molybdenum minerals. Gold-silver deposits occur in discontinuous quartz veins and fault gouge in metavolcanic rock, granite, and granodiorite and in shear zones containing quartz veins and siliceous zones in altered latite.

Tungsten is the most important mineral resource in the John Muir Wilderness. More than 1 million tons (0.9 million t) of tungsten resources ranging from 0.22 to more than 1.0 percent WO_3 exist, primarily along the edges of roof pendants. Gold, silver, copper, and molybdenum might be recovered as byproducts from most tungsten deposits. Molybdenum, gold, silver, copper, lead, and zinc occur as primary metals at several sites; these resources total about 47,000 tons (43,000 t). Although cobalt, uranium, talc, and optical calcite occur in the wilderness, resources are small.

Figure 2 shows areas with resource potential, and significant mines and prospects within these areas are listed in table 1.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

The locations of mines and prospects in or immediately adjacent to the John Muir Wilderness and areas with potential for undiscovered resources in the wilderness are shown in figure 2. Detailed information about those mines and prospects which have more than 1,000 tons (900 t) of resources is given in table 1. The areas with potential for additional resources are discussed below.

Area A: The Mount Morrison pendant area contains five mines or prospects with more than 1,000 tons (900 t) of resources: the Hard Point mine (loc. 4), the Lucky Strike prospect (loc. 5), Nicoll Hilton Creek mine and Filipelli prospect (loc. 8), Phelps Hilton Creek mine (loc. 9), and the Scheelore mine (loc. 6). These properties are in tactite or metasedimentary deposits, with related gold, silver, lead, copper, zinc, and tungsten mineralization. Three geochemically anomalous zones lie within this area. Anomalous amounts of zinc, chromium, lead, silver, copper, and gold are present in stream sediments south of Convict Lake. Near Esha Canyon, 2 mi west of Hilton Creek, and upper McGee Creek there are lead-copper-zinc anomalies attributable to the small deposits of these minerals scattered throughout the pendant (Rinehart and Ross, 1964). Stream-sediment samples anomalous in gold and molybdenum were collected in Laurel Creek, north of Bloody Mountain. The Hard Point mine (loc. 4), located at the head of Laurel Creek, consists of sulfide-rich tactite near the contact between the Round Valley Peak Granodiorite and calcareous metasedimentary rocks of the Bloody Mountain Formation. Area A is considered to have high favorability for undiscovered deposits of tungsten, lead, copper, zinc, gold, silver, and possibly molybdenum in calcareous metasedimentary rocks.

Area B: Metasomatic tungsten deposits occur at contacts between intrusive rocks and calcareous metasedimentary rocks of the Pine Creek pendant, a 7 mi (11 km) by 1 mi (1.6 km) belt extending from Basin Mountain to Wheeler Crest. The east side of the belt contains an extensive marble zone. Tungsten deposits are preferentially related to the most silicic intrusive rocks of the area (Bateman, 1965a). Over 70 percent of the known deposits are associated with the Tungsten Hills Quartz Monzonite or with alaskite. Of 20 mines and prospects located in area B, 8 have resources in excess of 1,000 tons (900 t): Round Valley Peak prospect (loc. 10), Brownstone mine[7] (loc. 13), Lambert mine (loc. 14), Tungstar mine (loc. 15), Alta mine (loc. 16), Sonny Boy mine (loc. 17), Hanging Valley mine (loc. 19), and Gable Lakes mine (loc. 20) have resources in excess of 1,000 tons (900 t). Production from Union Carbide Corporation mines at Pine Creek (loc. 12), adjacent to the wilderness, has been 4.5 to 5.0 million stu (41 to 45 million kg) WO_3, 5.5 million lb (2.5 million kg) copper, 7.0 million lb (3.2 million kg) molybdenum, and 1.0 million troy oz (5.6 million g) silver. Pine Creek mine is the largest tungsten producer in the United States today. Since 1916 production from the Pine Creek pendant area of the wilderness totals nearly 143,000 stu (1.3 million kg) WO_3. Area B has high favorability for undiscovered deposits of tungsten, molybdenum, copper, and silver in calcareous metasedimentary rocks.

Area C: Stream-sediment samples from the area around Hortense and Lee Lakes have anomalous concentrations of lead, gold, silver, zinc, copper, molybdenum, chromium, nickel, and manganese. The Pick and Shovel mine (loc. 3) within this area consists of quartz stringers and pods along joints in quartz monzonite and has indicated marginal resources of gold, silver, lead, copper, and zinc. The eastern part of the area may have tungsten resources in tactite deposits that are at the margins of small bodies of calcareous metasedimentary rocks. The favorability for undiscovered sulfide- and scheelite-bearing tactite deposits and lead, copper, zinc, gold, and silver deposits in veins in this area is judged to be moderate.

Area D: Stream-sediment samples from the area around Mammoth Creek are anomalous in gold, silver, and zinc, probably due to an altered zone in the metamorphosed latite of Arrowhead Lake. The Mammoth Consolidated mine (loc. 2), and several smaller mines and prospects are located just outside the wilderness in this alteration zone. The favorability for undiscovered gold-silver and possibly zinc deposits in metavolcanic rocks in this area is considered moderate.

Area E: The area east of Ruwau and Saddlerock Lakes in the upper Big Pine Creek drainage contains numerous small bodies of calcareous metasedimentary rocks; tungsten-bearing tactite deposits may occur at the contacts of these bodies with granitic rocks. Eleven stream-sediment samples from this area were anomalously high in silver. Most of these samples also had above-average concentrations of nickel and cobalt. The Bishop Silver-Cobalt mine (loc. 23) is located 2 mi (3.2 km) west of these sampling sites and consists of small silver-cobalt veins in gneiss. This area has moderate favorability for undiscovered tungsten-bearing tactite bodies and vein deposits of silver and possibly cobalt.

Area F: Stream-sediment samples from the area around Mount Humphreys were anomalous in molybdenum, copper, and silver. Bodies of metamorphosed calcareous sedimentary rocks in this area are similar to those associated with tactite deposits of tungsten elsewhere in the wilderness.

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[7] The portal of the Brownstone mine is less than 1,000 ft (300 m) outside the wilderness boundary.

Scheelite was observed in some tactite pods in these bodies. The Moly Blue prospect (loc. 22) consists of pods and veins of molybdenum minerals in siliceous zones in quartz monzonite; resources are indicated and inferred subeconomic. Area F is considered to have moderate favorability for undiscovered deposits of tungsten, copper, and silver in calcareous metasedimentary rocks and of molybdenum in siliceous zones in granitic rocks.

Area G: Geochemical analyses show anomalous zinc, gold, silver, lead, molybdenum, and copper in stream sediment samples from the area between Fish Valley and Mono Creek. This area of anomalies was recognized largely on the basis of analyses that were more sensitive than those done on stream-sediment samples collected elsewhere in the wilderness; the south and east boundaries of the anomaly probably reflect a change to a less sensitive analytical technique rather than to lower favorability for mineral deposits. The area has very low favorability for undiscovered deposits of lead, zinc, copper, gold, and silver in veins and joints.

Area H: The metamorphosed latite of Arrowhead Lake, exclusive of area D, constitutes area H. Known deposits and geochemical anomalies present elsewhere in this rock unit suggest that the area may have low favorability for undiscovered deposits of gold and silver in metavolcanic rocks.

Area I: Stream-sediment samples from the area between Bear Creek and Turret Peak contain anomalous amounts of gold, lead, tungsten, copper, and molybdenum, probably due to mineralization in several bodies of altered granitic rocks in the granite of Bear Dome (called the quartz monzonite of Bear Dome by Lockwood and Lydon, 1975) and in metavolcanic rocks nearby. There are no mines in the area, but a magnetic low 2.5 mi (4 km) west of Florence Lake is associated with a tungsten and molybdenum geochemical anomaly. Area I has low favorability for undiscovered deposits of gold, molybdenum, tungsten, lead, and copper associated with altered metavolcanic and granitic rocks.

Area J: Stream-sediment samples from the area east of Blackcap Mountain are anomalous in copper and lead. Other chemical analyses (Bateman and Lockwood, 1970) show that Cenozoic volcanic rocks similar to those in this area contain more copper, nickel, and chromium than the felsic granitic rocks on which the threshold values are based. There are no mines in the area. Favorability for undiscovered vein-type deposits of copper and lead is low.

Area K: Small masses of calcareous metasedimentary rocks are present in the area near Mount Pinchot, suggesting possible tungsten deposits in tactite at contacts with granitic rocks. A single stream-sediment sample collected in this area contained above-average amounts of nickel, copper, and chromium. This sample was collected near exposures of mafic plutonic rocks, richer in the anomalous elements than the granitic rocks upon which the threshold values are based (Rose and others, 1979). The favorability for undiscovered tactite occurrences with accompanying tungsten resources in this area is moderate; favorability for other mineralization is low.

Area L: Pods of calcareous metasedimentary rocks are present in contact with granitic rocks in the area between Lookout Point and the north fork of Oak Creek, suggesting possible tactite deposits. A large positive magnetic anomaly is centered over the area, and geochemical analyses of stream-sediment samples show anomalous copper, lead, and chromium. The magnetic anomaly probably is associated with relatively large amounts of magnetite in a large body of mafic plutonic rocks in the area; the geochemical anomaly probably is attributable to high background levels of the anomalous elements in the same body. The favorability for undiscovered tactite bodies with associated tungsten or sulfide mineralization in area L is moderate; favorability for small copper-lead deposits is low.

Area M: This area southeast of Baxter Pass contains mineralized vein quartz and fault gouge in the Oak Creek metavolcanic pendant and nearby granitic rocks; the Rex Montis mine (loc. 26) is in an indicated subeconomic deposit of this type, with only small amounts of gold and silver. Analyses of the stream-sediment samples in the northwestern part of this area show minor copper and nickel. Area M has moderate favorability for undiscovered vein deposits of gold and silver and possibly nickel and copper.

Area N: Stream-sediment samples collected near metavolcanic rocks in this area are weakly anomalous in lead and copper. A weak silver anomaly located in the Symmes Creek watershed, 1 to 2 mi north of Shepherd Creek, is probably derived from glacial till. This area has low favorability for undiscovered deposits of lead, copper, and silver associated with metavolcanic rocks.

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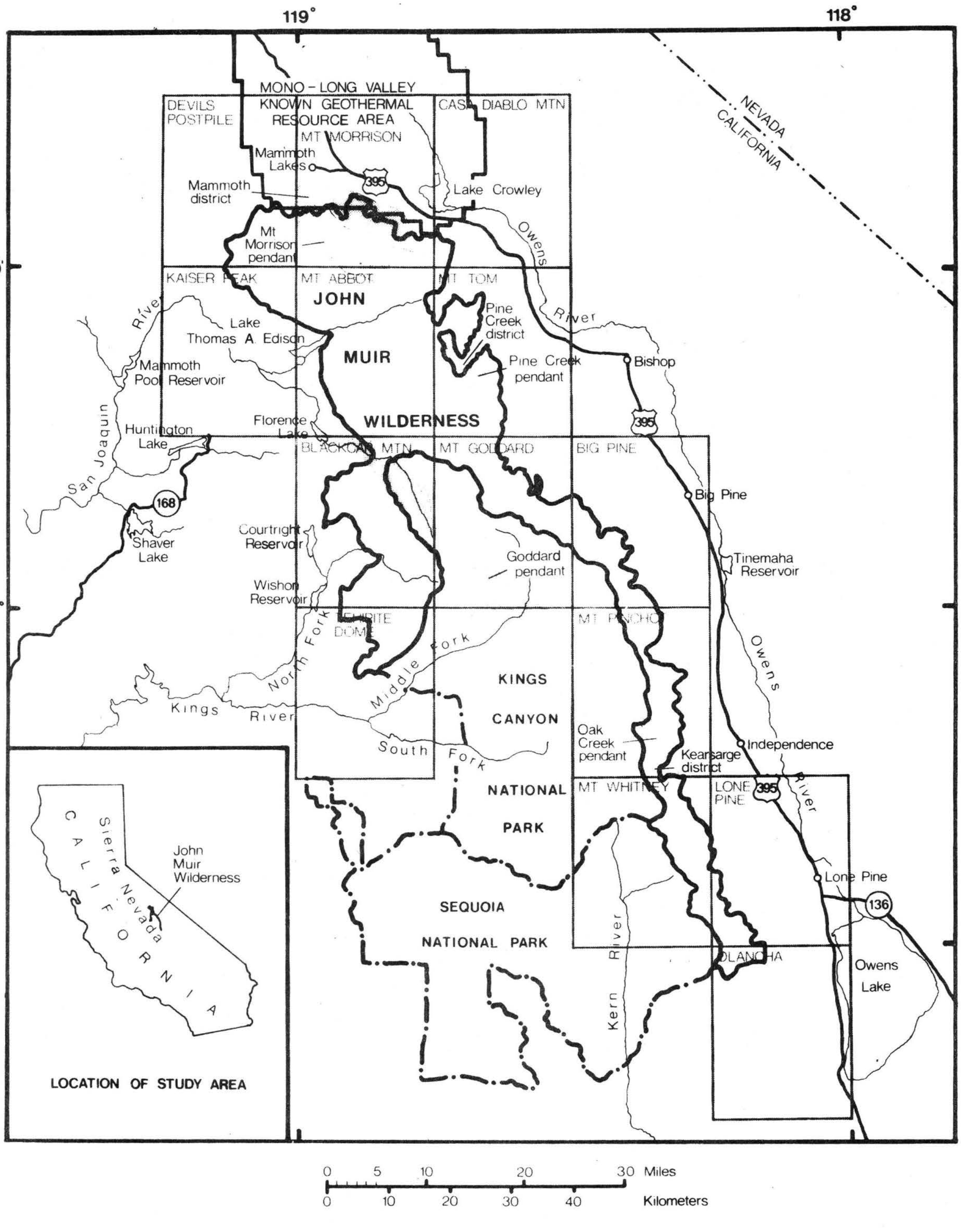

Figure 1.--Index map showing location of John Muir Wilderness and surrounding area.

Table 1.--Mines and prospects with 1,000 tons (900 t) or more resources in the John Muir Wilderness

Prospect name	Map number	Type of occurrence	Resource classification[1]	Tons	(tonnes)	Average grade
			Pine Creek pendant area			
Alta mine	16	Garnet-hedenbergite tactite at contact of intrusive with metasedimentary rock	Indicated subeconomic	1,600	(1,500)	0.22 percent tungsten trixoide (WO_3)
Brownstone mine[2]	13	Inclusion of marble and tactite in quartz monzonite	Inferred	Estimated thousands of tons. Data not available; Union Carbide Corp., owner		Probably 0.5 to 1 percent tungsten trioxide (WO_3)
Gable Lakes mine	20	Inclusion of marble, tactite, quartzite, and schists in quartz diorite	Indicated subeconomic	14,000	(13,000)	0.26 percent tungsten trioxide (WO_3)
Hanging Valley mine	19	Zone of marble, tactite, and hornfels intruded by irregular masses of quartz monzonite	Indicated marginal	3,100	(2,800)	0.38 percent tungsten trioxide (WO_3)
Lambert mine	14	Pendant of marble, tactite, and quartzite enclosed in quartz monzonite	Indicated subeconomic	13,000	(12,000)	0.27 percent tungsten trioxide (WO_3)
			Inferred subeconomic	46,000	(42,000)	0.28 percent tungsten trioxide (WO_3)
Round Valley Peak	10	Garnet-epidote-quartz tactite at contact of marble with Wheeler Crest Quartz Monzonite	Indicated marginal	250,000	(230,000)	0.5 prospect tungsten trioxide (WO_3)
Sonny Boy mine	17	Quartz-epidote-rich tactite at contact of marble with quartz monzonite and quartz diorite	Indicated marginal	36,000	(33,000)	0.31 percent tungsten trioxide (WO_3)
Tungstar mine	15	Garnet-epidote tactite bodies in quartz diorite	Indicated marginal	7,600	(6,900)	0.91 percent tungsten sten trioxide (WO_3)
			Mount Morrison pendant area			
Hard Point mine	4	Sulfide-rich tactite pods at near horizontal contact of calcareous metasedimentary rocks and granodiorite	Indicated reserves	16,000	(14,500)	1.0 percent tungsten trioxide (WO_3). Minor copper, molybdenum, and silver
			Inferred reserves	No data available		

Lucky Strike prospect	5	Sulfide-rich siliceous metasedimentary zone in Mount Baldwin Marble	Indicated marginal	6,200	(5,600)	0.54 oz silver per ton (19 g/t), 0.40 percent copper, 0.32 percent lead, and 5.45 percent zinc
Nicoll Hilton Creek mine and Filipelli prospect	8	Tactite at contact of marble with diorite or quartz monzonite	Indicated marginal	4,400	(4,000)	0.71 percent tungsten trioxide (WO_3)
Phelps Hilton Creek mine	9	Sulfide-rich tactite near contact of marble and quartz monzonite	Indicated marginal	550,000	(500,000)	0.23 percent tungsten trioxide (WO_3)
			Indicated marginal	1,100	(1,000)	0.45 oz gold per ton (15 g/t)
Scheelore mine	6	Tactite and quartz-pyrite-limonite pods along contacts of marble and granodiorite	Indicated and inferred marginal	57,000	(52,000)	0.89 percent tungsten trioxide (WO_3)
			Sierra front area			
Snow White Nos. 1-5 prospect	25	Garnet-diopside-quartz tactite at contact of diorite with calc-hornfels	Indicated subeconomic	4,200	(3,800)	0.16 percent tungsten trioxide (WO_3)
			Kearsarge mining district			
Rex Montis mine	26	Vein quartz and fault gouge containing sulfides in metavolcanic and granitic rocks	Indicated subeconomic	8,000	(7,000)	0.17 oz gold per ton (0.583 g/t), 0.950 oz silver per ton (32.6 g/t)
			Miscellaneous outlying areas			
Pick and Shovel mine	3	Quartz stringers and pods along joints in granodiorite	Indicated marginal	1,000	(900)	0.002 oz gold per ton (0.069 g/t), 0.42 oz silver per ton (14 g/t), 0.23 percent copper, 0.15 percent lead, 0.18 percent zinc
Moly Blue prospect	22	Pods and veins of molybdenum minerals in siliceous zones in granodiorite	Indicated subeconomic	2,000	(2,000)	0.26 percent molybdenum
			Inferred subeconomic	28,000	(25,000)	0.07 percent molybdenum

[1]Classification used by U.S. Bureau of Mines and U.S. Geological Survey (1980).

[2]The portal of the Brownstone mine is less than 1,000 ft (300 m) outside the wilderness boundary; resources there may extend into the wilderness.

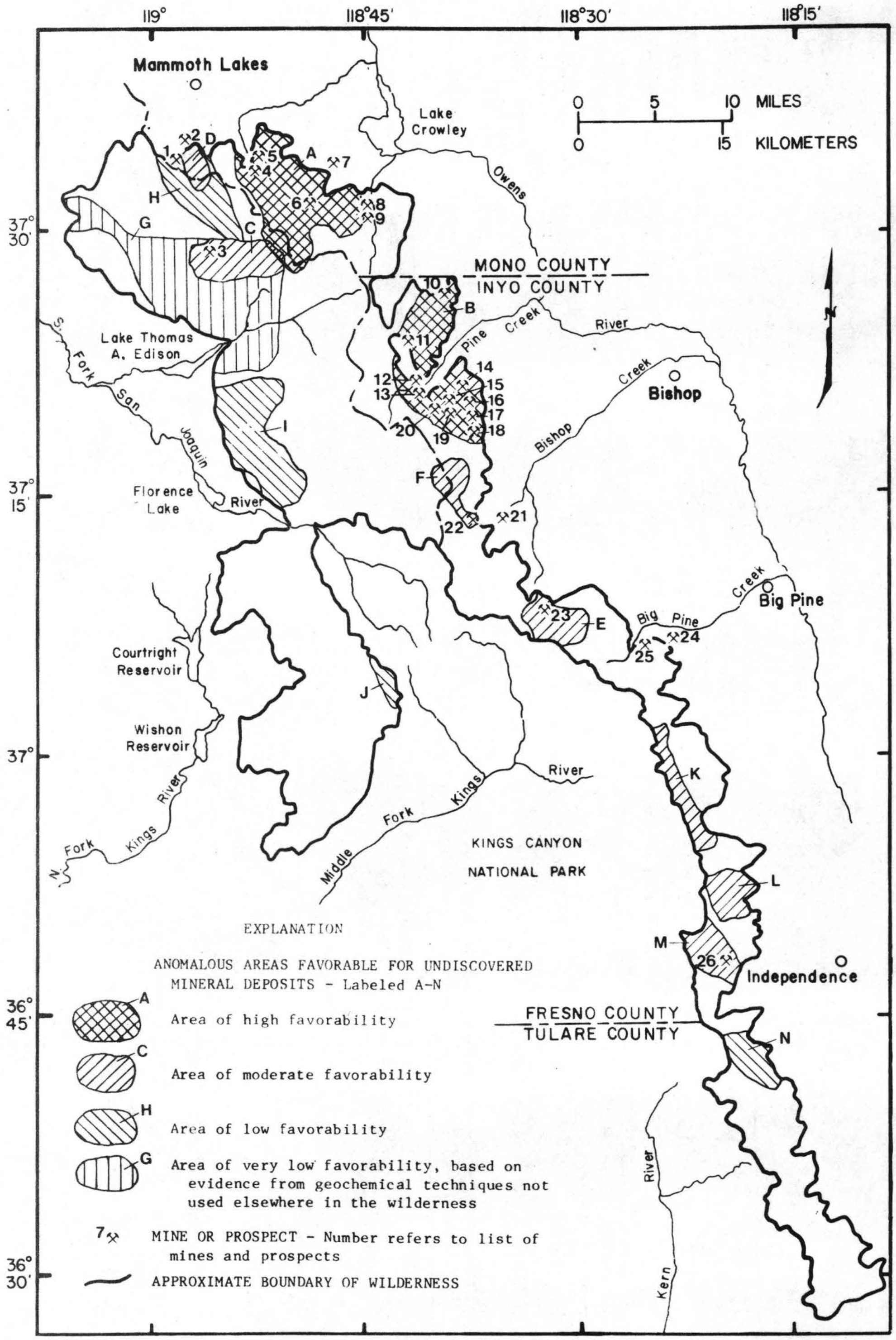

Figure 2.--Areas with mineral resource potential and location of mines and prospects in the John Muir Wilderness.

MINES AND PROSPECTS

1. Emerald Lake prospect
2. Mammoth Consolidated mine
3. Pick and Shovel mine
4. Hard Point mine
5. Lucky Strike prospect
6. Scheelore mine
7. Tiptop prospect
8. Nicoll Hilton Creek mine and Filipelli prospect
9. Phelps Hilton Creek mine
10. Round Valley peak prospect
11. Adamson mine
12. Pine Creek mine
13. Brownstone mine
14. Lambert mine
15. Tungstar mine
16. Alta mine
17. Sonny Boy mine
18. Basin Mountain prospect
19. Hanging Valley mine
20. Gable Lakes mine
21. Cardinal mine
22. Moly Blue prospect
23. Bishop Silver-Cobalt mine
24. Blue Star Talc mine
25. Snow White Nos. 1-5 prospect
26. Rex Montis mine