DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-1380-C
PAMPHLET

MINERAL RESOURCE POTENTIAL OF THE GLACIER PEAK ROADLESS AREA, SNOHOMISH COUNTY, WASHINGTON

By

S. E. Church and R. W. Tabor, U.S. Geological Survey
and
F. L. Johnson, U.S. Bureau of Mines

STUDIES RELATED TO WILDERNESS

Under the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and related acts, the U.S. Geological Survey and the U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the acts were passed were incorporated into the National Wilderness Preservation System, and some of them are currently 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 Glacier Peak Roadless Area (L6031), Mount Baker-Snoqualmie National Forest, Snohomish County, Wash. The Glacier Peak Roadless Area was classified as a further planning area during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January 1979.

MINERAL RESOURCE POTENTIAL SUMMARY STATEMENT

A multidisciplinary team of geoscientists from the U.S. Geological Survey and the U.S. Bureau of Mines has evaluated the potential for the occurrence of mineral resources in the Glacier Peak Roadless Area. The area includes all, or parts of four mining districts; past production records are poor, but an estimated 280,000 tons of high-grade gold-silver-copper-lead-zinc ore was produced from sulfide veins at the turn of the century. Forty-seven million tons of restricted marginal reserves and 6 million tons of subeconomic resources have been identified at 16 properties in the Glacier Peak Roadless Area. The reserves are classified as "restricted marginal" because of current environmental regulations on the production and disposal of arsenic-bearing materials. New ore-processing methods currently under development, however, may make these marginal reserves economically viable.

The sulfide veins are distributed along shears and joints in a northeast-trending zone, mostly where it intersects north-trending tonalite intrusions presumed to have intruded along the trace of the Straight Creek fault. Geologic and geochemical data indicate a high potential for the occurrence of base- and precious-metal resources for most of the belt; a moderate potential, however, is assigned to this trend in the Goat Lake mining district.

Geologic and geochemical data suggest a porphyry-copper deposit near the headwaters of Silver Creek. Examination of mines and drill-hole data indicate a resource of 110 million tons of disseminated copper sulfides ranging from 0.14-0.37 percent copper with gold as a coproduct in a volcanic porphyry deposit. Geologic data suggest that this deposit extends into the Troublesome Creek mining district within the Glacier Peak Roadless Area. The area at the headwaters of Silver Creek has a high potential for the occurrence of base-metal resources in a disseminated porphyry-copper deposit. Further drilling will be needed to define this possible deposit.

INTRODUCTION

The Glacier Peak Roadless Area, in Mount Baker-Snoqualmie National Forest, in Snohomish County, is near, but not quite contiguous with the Glacier Peak Wilderness (see fig. 1). The Eagle Rock Roadless Area lies just to the south. The 57,320 acres (89.5 mi^2) of the Glacier Peak Roadless Area include very rugged mountainous terrain north of the North Fork of the Skykomish River and between the North and South Forks of the Sauk River. Relief is great; elevations range from about 1,500 ft near the confluence of the North and South Forks of the Sauk River to about 7,800 ft at the summit of Sloan Peak.

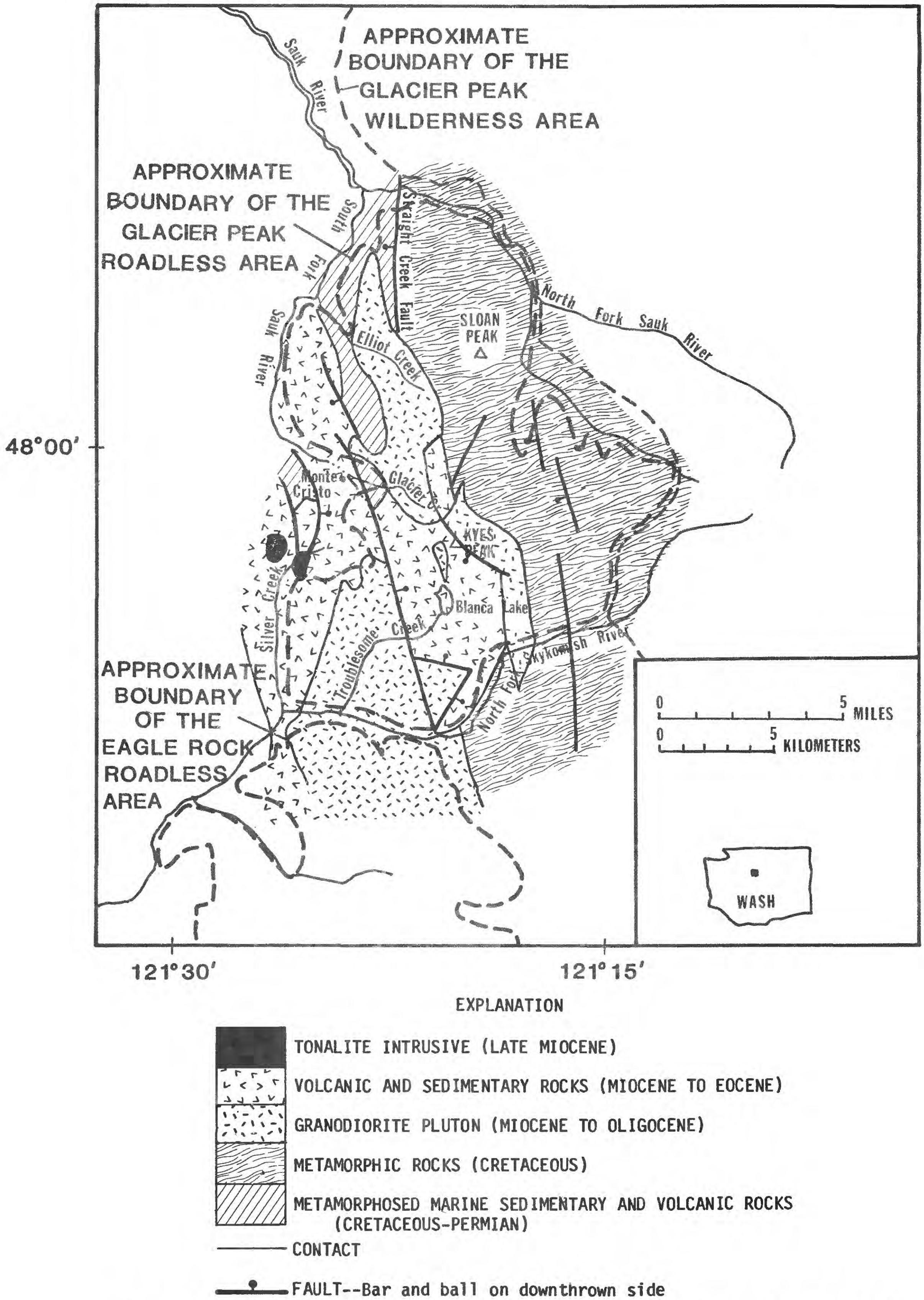


Figure 1.—Index map and simplified geologic map of the Glacier Peak Roadless Area, L6031 (geology after Tabor and others, 1982b).

Located on the west side of the Cascade crest, the area receives heavy precipitation. Very dense brush and forest cover the area from valley floors to about 4,500 ft elevation. This climate, combined with the rough topography, creates unusually severe prospecting and mining problems. Snow starts accumulating at higher elevations in September and severe avalanche conditions persist from late October through early June. Snow depths may reach as much as 10 ft in Monte Cristo and 30 ft on the higher slopes during hard winters. Glacier-clad peaks rise abruptly 4,000-4,500 ft above the site of the old mining town of Monte Cristo. Roads from Monte Cristo, more or less in the center of the area, lead 35 mi west over Barlow Pass to Granite Falls and 30 mi north down the Sauk River to Darrington.

Present and previous studies

This report summarizes studies by the U.S. Geological Survey and the U.S. Bureau of Mines, designed to evaluate the mineral potential of the Glacier Peak Roadless Area. Investigations by the U.S. Geological Survey included geologic mapping (Tabor and others, 1982b), geochemical reconnaissance (Church and others, 1982), and aeromagnetic surveys (Flanigan and others, in press) conducted from 1978-1982. Detailed investigations by the U.S. Bureau of Mines of the mining activity and production, and field studies of mines and prospects were made during the 1976-1981 field seasons (Johnson and others, 1983). The roadless area includes the Troublesome Creek mining district and major portions of the Monte Cristo, Goat Lake and Silver Creek mining districts.

Over 4,000 claims have been located in or near the roadless area. One hundred ninety-six patented claims are in or within 1 mi of the area. We examined 162 underground and 43 surface workings, and collected and analyzed more than 2,000 samples from the mine workings, stockpiles, and dumps to define ore suites, and to determine ore grades. Complete sample analyses are on file at the U.S. Bureau of Mines, Western Field Operations Center, Spokane, Wash. We also briefly studied the terrain in drainages having geochemical anomalies and sampled altered zones identified during the geologic mapping (Church and others, 1983, in press).

In addition to this study, the U.S. Bureau of Mines examined many of the mines and prospects in the Silver Creek mining district during the 1950's (MaGill and Schalagel, 1962). J. E. Spurr (1901) of the U.S. Geological Survey examined the Monte Cristo mining district and his findings, coupled with labor problems and floods, caused the closing of the mining district in the early 1900's. Many mining companies were active in the roadless area from the early 1890's through the 1930's (Woodhouse, 1979). More recently, Texasgulf, Inc., Exxon Minerals Co., Cities Service Co., Duval Corp., Nord Resources Corp., Tanda Exploration, Burlington Northern, Inc., Bear Creek Mining Co., Bren Mac Mines Ltd., Bethex Corp., and others have been exploring in the area. Development work was in progress at the Shamrock prospect in the Troublesome Creek mining district during the summer of 1981.

ACKNOWLEDGMENTS

Collection of samples discussed in this report required the diligent and often laborious efforts of many. The field studies were greatly aided by the skill of our helicopter pilots, Anthony Reece, Doug Bucklew, LeRoy Brown, Ben VanEtten, Timothy Wiltrout, Jerry Wise, and the late Jack Johnson. We thank Derek Booth, Paul Carroll, Brett Cox, Virgil Frizzell Jr., Jean Hatherington, Sam Johnson, Kathy Lombardo, Joe Marquez, Elizabeth Mathieson, Jim Talpey and John Whetten for their assistance in collecting geological and geochemical samples. We thank James Frisken, William Kemp and Scott Werschky for their assistance in examining mineralized structures. We also wish to thank David Denton, Stephen Iverson, Robin McCulloch, Scott Stebbins, and Ronald Stotelmeyer for their work in evaluating the data from the mines and prospects.

Terry Close, Fred Spicker, Rod Jeske, Dale Avery, Bill White, Mike DeVeau, Jim Werle, Jim Rigby, Doug Harby, Jeff Wilson, Randy Cross, Jim Greeves, Larry Reigel, Sue Lupinski, Rob Collins, Steve Drussel, Craig Rankin, Stuart Simpson, Corolla Hoag, Susan Douglas, Kevin Lakey, Glen Carter, Ruth Satterlund, Bill Wickstrom, Dominic Winslow, Dave Hatfield, and Rick Fredricksen also assisted in the sampling of mines and prospects study by the U.S. Bureau of Mines.

Mike King and John Robinson of the U.S. Forest Service furnished information regarding claims, access routes, and names of claim owners. Phillip R. Woodhouse, author of the book "Monte Cristo," was especially helpful in providing information on the mining history. Jerod Rosman, currently a resident of Monte Cristo, was very supportive.

GEOLOGY, GEOCHEMISTRY, AND GEOPHYSICS PERTAINING TO MINERAL RESOURCE ASSESSMENT

Geology

The Glacier Peak Roadless Area is roughly divided into two geologic terranes by the north-trending Straight Creek fault, a major Pacific Northwest structure which may have had considerable strike-slip movement prior to the Tertiary (Vance and Miller 1981). The fault separates the low-grade Darrington Phyllite of Misch (1966) and the metamorphic Jurassic and Permian age rocks on the west (see fig. 1), from higher grade metamorphic rocks of the north Cascades crystalline core, mostly the metamorphosed shales of the Chiwaukum Schist, banded gneiss derived from the schist, and gneissic Sloan Creek plutons (metamorphic rocks of Cretaceous age) to the east.

Through most of the roadless area, the Straight Creek fault zone has been intruded by tonalite and granodiorite of the Miocene Grotto batholith (25 m.y. old). The Grotto batholith has been dated by numerous potassium-argon analyses, yielding nearly concordant hornblende and biotite ages that are essentially the same as those for the larger Snoqualmie batholith exposed to the south of the area.

The Grotto batholith, a granodiorite pluton of Miocene age that appears to have intruded the Straight Creek fault (see fig. 1), now separates the higher grade metamorphic rocks on the east from relatively unmetamorphosed marine sandstone, shale, basalt, and chert as well as ultramafic rocks, all part of a major melange belt. The constituents of the melange range in age from Permian to Triassic and possibly Jurassic (Tabor and others 1982a; 1982b). The melange is overlain by strongly folded fluviatile, feldspathic sandstone of the Eocene Swauk Formation, the principle host for mineralization in the Silver Creek mining district, which we show as a part of the Miocene and Eocene volcanic and sedimentary rocks (fig. 1).

The melange rocks, the Swauk Formation, the Darrington Phyllite, and the metamorphic rocks east of the Straight Creek fault are overlain unconformably by the Barlow Pass volcanic rocks of Vance (1957b), which are also included in the volcanic and sedimentary rock unit (fig. 1). The rocks of the Barlow Pass unit are folded basalt and rhyolite flows, tuffs and breccias with minor andesite and interbeds of feldspathic sandstone. In the roadless area the volcanic rocks are highly altered and locally recrystallized to hornfels by the Tertiary plutons. Correlation with rocks of similar lithology and stratigraphic position indicates that the Barlow Pass volcanic rocks are probably late Eocene to early Oligocene in age (Vance 1957a; R. W. Tabor, unpub. data, 1983). In the Monte Cristo mining district, Barlow Pass volcanic rocks are a principal host for ore minerals.

Slightly younger than the Miocene Grotto batholith, and included with it, is the breccia of Kyes Peak (Tabor and others, 1982b), a gently deformed andesitic to dacitic breccia. The Kyes Peak unit is locally rich in angular fragments of the older volcanic, metamorphic, and plutonic rocks. The breccia appears to be confined to a north-northwest-trending graben between two major faults. Clasts of brecciated phyllite as much as 2,000 ft long and 200 ft thick indicate catastrophic deposition, perhaps during tectonic subsidence. Fission track ages from zircon, and potassium-argon ages from the breccia of Kyes Peak, indicate eruption between 34 and 24 m.y. ago. (Vance and Naeser, 1977). Clasts of tonalite in the breccia where it rests on Grotto batholith above Seventysix Gulch (Spurr, 1901 p. 800; Heath, 1971, p. 126) suggest that the breccia is younger than the batholith (25 m.y.).

The youngest tonalite intrusions crop out in the upper reaches of Silver Creek (late Miocene tonalite, fig. 1). On the basis of concordant potassium-argon ages from hornblende and biotite from one body, these small, somewhat porphyritic stocks, plugs, and dikes are about 20 m.y. old (Tabor and others 1982a). A mineralized explosion breccia overlies one of the stocks just outside the roadless area and may have developed as the stock degassed. A 10-ft block of breccia having sulfide cement that we found in Silver Creek testifies to the existence of another explosion breccia somewhere higher in the drainage. The small tonalite intrusions are part of a linear array of small stocks and plugs extending northeastward to the 23 m.y. old Cloudy Pass batholith in the Glacier Peak Wilderness. This linear array is also reflected in geochemical anomalies and is more or less coincident with the northeast trending Glacier Peak transverse structural belt of Grant (1969, p. 40-41).

Mineral resources in the roadless area occur in northeast-trending, sulfide-bearing quartz veins and shear zones associated with the tonalite intrusions. Mineralization may have been controlled by the intersection of the northwest-trending Straight Creek fault system with the Glacier Peak transverse structural belt. The structural belt is characterized by an en echelon, northeast-trending shear and fracture system traceable from the west edge of the Index mining district, which is south of the roadless area, into the Glacier Peak Wilderness (see fig. 2).

Geochemistry

We divided geochemical investigations of the roadless area into three parts, each having a specific objective: (1) bedrock geochemistry, (2) stream-sediment geochemistry, and (3) analysis and investigation of altered areas indicated by geologic studies, mining activity, and geochemical reconnaissance of drainage basins. Analytical results from the bedrock geochemical studies (Church and others, 1983) define the background and threshold values for the rock units; Church and others (in press) present a geologic interpretation of the geochemical reconnaissance survey of the Glacier Peak Roadless Area.

We collected 148 stream-sediment samples from the roadless area in conjunction with the geologic mapping. Sampled stream basins had areas as large as 3 mi^2. In addition, we collected 40 heavy-mineral concentrates panned from stream sediments from larger, second-order drainage basins. All analytical results (Church and others, 1982) were obtained using direct-current emission spectrography (Grimes and Marranzino, 1968).

Numerous geochemical anomalies occur in the roadless area (Church and others, in press); anomalies are large, many exceeding ten times the value defined for the threshold value from the bedrock geochemistry. Anomalies from the different mining districts differ only slightly. The Silver Creek mining district contains anomalous concentrations of copper (Cu), cobalt (Co), molybdenum (Mo), tungsten (W), tin (Sn), arsenic (As), gold (Au), lead (Pb), zinc (Zn), silver (Ag), and bismuth (Bi) in almost every drainage basin sampled. In contrast, the Monte Cristo mining district showed no anomalous concentrations of bismuth. The Troublesome Creek mining district (see fig. 3) contains many of the same anomalous elements on the west side of the district where it adjoins the Silver Creek mining district, but only Cu, Pb, Sn, As, Sb, and Au are found on the east side of the district. The Goat Lake mining district, north of the Monte Cristo mining district (see fig. 3) also contains anomalous concentrations of mercury (Hg) in addition to many of the elements found in the Silver Creek mining district, but the anomalies are generally smaller, about three times the threshold values. These elements are typical of the precious-metal and base-metal suites of both porphyry

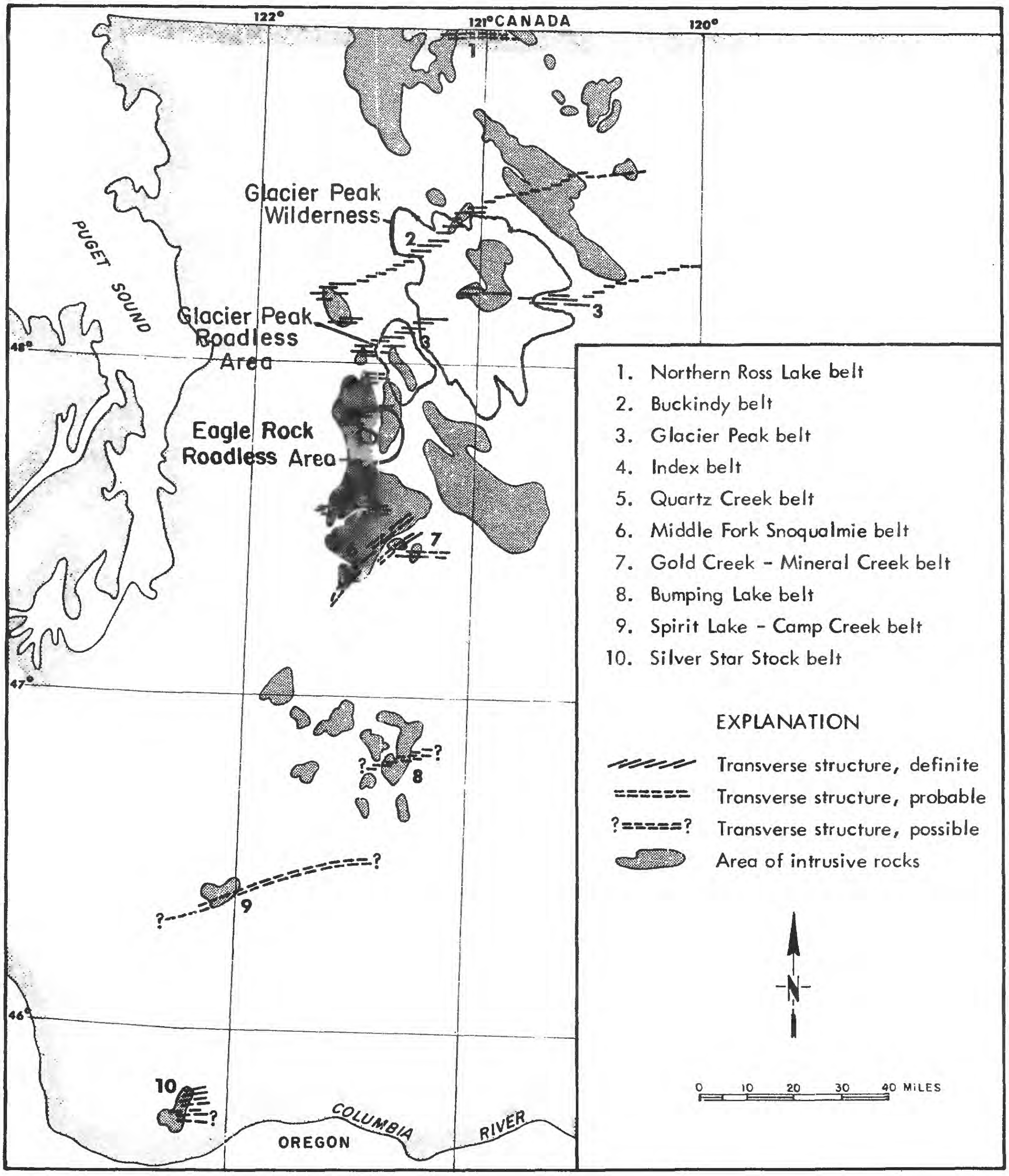


Figure 2.—Map of the known and suspected transverse structural belts in the Cascade Range, northern Washington (from Grant, 1969, p. 40).

and associated hydrothermal vein deposits (Pilcher and McDougall, 1976; Chaffee, 1982a; Berger and Eimon, 1983), and reflect the mineralogy of the veins found in the Monte Cristo and Silver Creek mining districts.

Geophysics

Magnetic data from the roadless area were examined in conjunction with an aeromagnetic survey of the Glacier Peak Wilderness (Flanigan and others, in press). The data were compiled from several aeromagnetic surveys; flight directions for the aeromagnetic surveys were generally northeast-southwest, transverse to the regional structure. Flight lines were drape-flown at about 1000 ft above the terrain on a 0.5 mi spacing. Topographic anomalies are inherent in the data due to imperfect draping in the steep terrain. The magnetic character of the Glacier Peak Roadless Area exhibits a highly complex pattern characteristic of volcanic terranes (Flanigan and others, in press). No diagnostic magnetic signature could be discerned when compared with the distribution of known deposits in the roadless area except that a magnetic low may be associated with the northeast-trending "Glacier Peak" belt containing the major mineralization (fig. 2).

MINING DISTRICTS AND MINERALIZATION

Exploration in the Glacier Peak Roadless Area began in the 1870's in the Silver Creek mining district and spread to the Monte Cristo mining district in 1889. Although exploration activity in the Silver Creek mining district has been intense, nearly all ore production has been from polymineralic sulfide-bearing quartz veins of the Monte Cristo mining district. Mining activity was greatest during the late 1800's and early 1900's. Exploration activity in the Goat Lake and Troublesome Creek mining districts has been moderate, but there is no recorded production from either district.

Over 4,000 mining claims had been located in or near the Glacier Peak Roadless Area by summer 1979, and 196 patented claims are in or within 1 mi of the roadless area. A few placer claims have been located along drainage bottoms, mainly Glacier Creek, Silver Creek, Troublesome Creek, Elliott Creek, and the South Fork of the Sauk River. Of the total number of claims, over 2,500 were in the Silver Creek mining district, 1,130 in the Monte Cristo mining district, 180 in the Troublesome Creek mining district, 179 in the Goat Lake mining district, and about 100 in outlying portions of the roadless area.

Monte Cristo mining district

The Monte Cristo mining district (fig. 3) is in the west-central part of the roadless area. Until 1981, it was accessible by a county gravel road from Barlow Pass, but washouts have made the town site accessible only by a four-wheel-drive vehicle. Philip Woodhouse (1979) has studied the mining history of the region and we have used data from his book freely.

Prospecting in the district began in the spring of 1889 when Joe Pearsall found sulfide-bearing quartz veins as rich as "Monte Cristo." Pearsall, accompanied by Frank Peabody, staked the Independence of 1776 on July 4, 1889, the first mining claim in the district. Claim staking and development work gained momentum after Joe Pearsall's first visit.

Stories about the ore deposits in the district were making headlines from coast to coast and this prompted investors, including John D. Rockefeller, to buy into the mines. By spring 1891 construction of a road up the Sauk River had begun; on September 6, 1893, the Everett and Monte Cristo Railroad was completed, and the first scheduled train reached Monte Cristo.

During the early 1890's, while the railroad was being constructed, development at the mines was continuing at a fast pace. In 1893 work began on a 300 ton-per-day concentrator and tramways to the Mystery (fig. 3, no. 33) and Pride of the Mountains (fig. 3, no. 23) mines. The tramways were completed in early August 1894. The concentrator began treating ore from the district on August 20, 1894, and the first concentrates were shipped to the Everett smelter shortly thereafter.

The town of Monte Cristo grew and prospered as the mines produced high-grade ore, reaching record levels each year until November 19, 1897, when massive floods destroyed much of the railroad. Investors announced that the railroad would not be rebuilt; and most mining ceased in the district in December 1897.

Rockefeller gained controlling interest in the Monte Cristo mines and attendant companies by early 1899. Railroad service was restored to Monte Cristo during the summer of 1900, and mining began again. J. E. Spurr (1901), of the U.S. Geological Survey, studied the geology and ore deposits in the district and concluded that the ore value decreased with depth. After Spurr's report was published, Rockefeller began selling his holdings; the Guggenheim smelter trust, later to be known as ASARCO, acquired the Monte Cristo Mines and the Everett smelter. The company was interested mainly in the smelter, so the mines were shut down in 1903. Limited production resumed in 1906, but the mines were closed again in the fall of 1907. Several feeble attempts were made to revive mining in the district through the winter of 1920 without success. The district has been idle since.

The most important deposit in the Monte Cristo mining district lies along a northeast-trending, northwest-dipping shear zone. Production records for the district are sketchy, but at least 280,000 tons of polymineralic-sulfide ore was produced (see fig. 3 and table 1); most ore came from the Mystery (no. 33), New Discovery (no. 22), Pride of the Mountains (no. 23), Pride of the Woods (no. 28), Golden Cord (no. 36), Comet (no. 40), Justice (no. 35), and Rainy mines (no. 34).

Silver Creek mining district

The Silver Creek mining district extends into the southwest part of the roadless area. The first mining claims in the district were located by George White and Hill Tyler in 1871. A rush of prospectors resulted in establishment of the town of Silver City near the

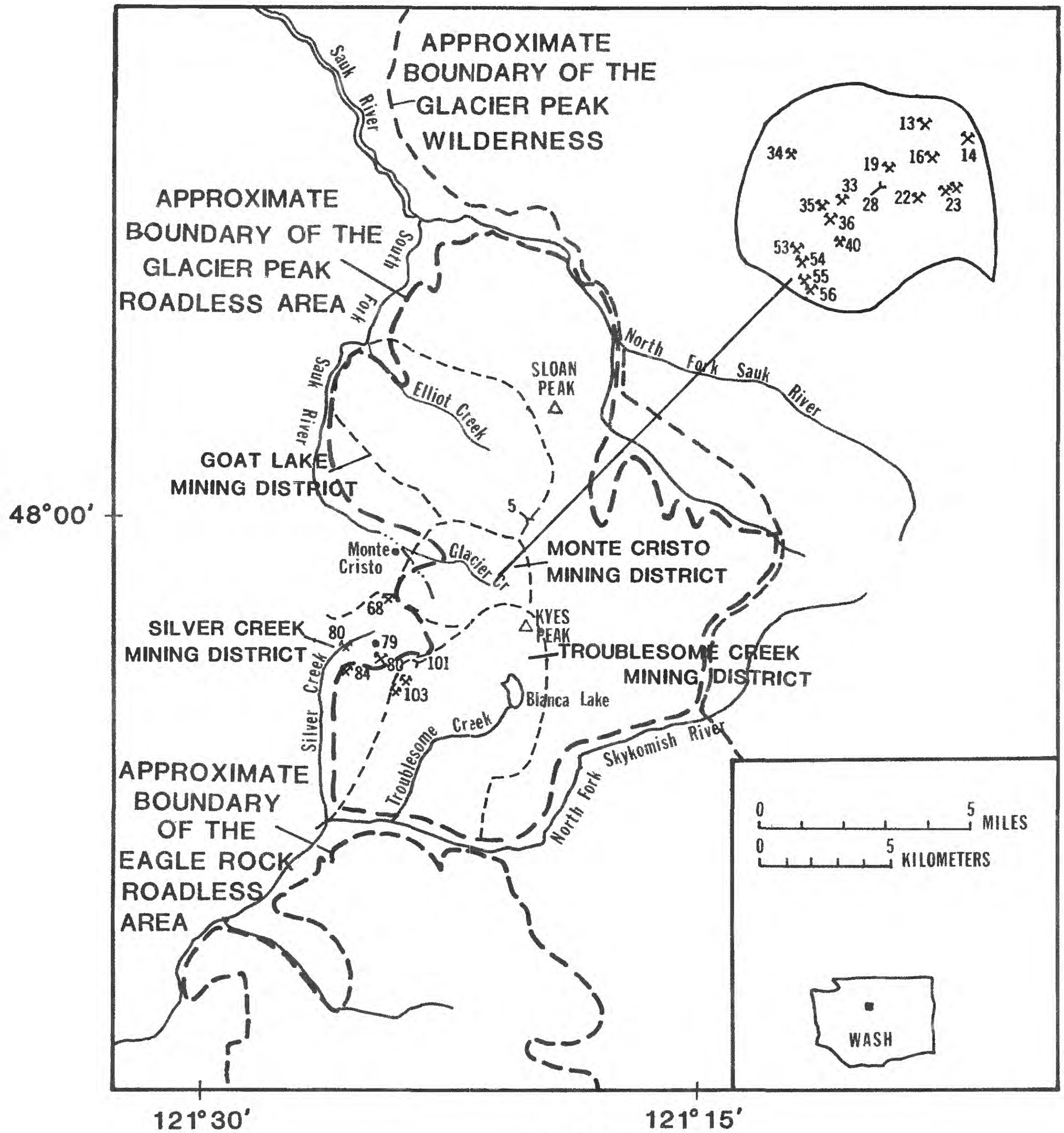
Table 1.--Mines and prospects having identified mineral resources in and near the Glacier Peak Roadless Area

[Properties with an asterisk are outside the roadless area; classification according to U.S. Bureau of Mines and U.S. Geological Survey, 1980]

No. on fig. 3	Name	Resources: Classification	Resources: Tons	Resources: Grade
13	Whistler-----	Indicated and inferred, restricted marginal reserve.	12,000	0.619 oz gold per ton, 2.1 oz silver per ton, 0.34 percent copper, 0.46 percent lead, 2.05 percent zinc, 10.76 percent arsenic, and 0.12 percent antimony.
14	Hilda--------	Indicated and inferred, subeconomic.	10,000	0.276 oz gold per ton, 11.9 oz silver per ton, 1.04 percent copper, 1.73 percent lead, 3.41 percent zinc, 4.46 percent arsenic, and 1.00 percent antimony.
16	Pica---------	Inferred, subeconomic---	7,800	0.212 oz gold per ton, 2.0 oz silver per ton, 0.15 percent copper, 0.48 percent lead, 4.34 percent zinc, 3.78 percent arsenic, and 0.14 percent antimony.
19	Philo--------	Indicated and inferred, restricted marginal reserve.	330,000	0.371 oz gold per ton, 0.8 oz silver per ton, 0.12 percent copper, 0.30 percent lead, 3.36 percent zinc, 9.48 percent arsenic, and 0.18 percent antimony.
22	New Discovery mine.	Indicated and inferred, restricted marginal (upper block).	2,500,000	0.147 oz gold per ton, 1.15 oz silver per ton, 0.07 percent copper, 0.41 percent lead, 1.32 percent zinc, and 2.83 percent arsenic.
		Inferred, restricted marginal reserve (lower block).	1,900,000	
23	Pride of the Mountains mine.	Indicated and inferred, restricted marginal reserve (upper block).	17,000,000	0.144 oz gold per ton, 1.37 oz silver per ton, 0.137 percent copper, 0.76 percent lead, 0.91 percent zinc, and 2.65 percent arsenic.
		Inferred, restricted marginal reserve (lower block).	11,000,000	
33	Mystery mine	Indicated and inferred, restricted marginal reserve (upper block).	6,800,000	0.069 oz gold per ton, 1.7 oz silver per ton, 0.13 percent copper, 0.50 percent lead, 0.75 percent zinc, 2.13 percent arsenic, and 0.36 percent antimony.
		Inferred, restricted marginal reserve (lower block).	5,500,000	
34	Rainy mine*	Inferred, restricted marginal reserve (from company data).	100,000	0.56 oz gold per ton and 2.6 oz silver per ton.
35	Justice mine	Indicated and inferred, subeconomic (upper block).	3,000,000	0.044 oz gold per ton, 0.59 oz silver per ton, 0.01 percent copper, 0.206 percent lead, 0.295 percent zinc, and 1.40 percent arsenic.
		Inferred, subeconomic (lower block).	2,600,000	
36	Golden Cord mine.	Resources are reported as part of Justice mine.		
40	Comet mine---	Indicated and inferred, subeconomic.	110,000	0.134 oz gold per ton, 2.5 oz silver per ton, 1.02 percent lead, 1.22 percent zinc, and 3.15 percent arsenic.
53	Hannah-------	Inferred, restricted marginal reserve (upper vein).	31,000	0.18 oz gold per ton, 25.5 oz silver per ton, 22.2 percent lead, and 9.9 percent zinc.
		Indicated and inferred, subeconomic (lower vein).	2,000	0.14 oz gold per ton, 1.32 oz silver per ton, 0.41 percent lead, 3.73 percent zinc, and 3.70 percent arsenic.

Table 1.--Mines and prospects having identified mineral resources in and near the Glacier Peak Roadless Area--(Continued)

No. on fig. 3	Name	Resources: Classification	Tons	Grade
54	Emma Moore---	Indicated and inferred, subeconomic.	30,000	0.025 oz gold per ton, 4.0 oz silver per ton, 0.04 percent copper, 3.35 percent lead, 3.93 percent zinc, and 2.83 percent arsenic.
55	Seventy-four	Indicated and inferred, subeconomic	6,000	0.415 oz gold per ton, 7.8 oz silver per ton, 0.17 percent copper, 4.10 percent lead, 12.9 percent zinc, 0.98 percent arsenic, and 0.16 percent antimony.
56	Congress-----	Indicated and inferred, restricted marginal reserve.	8,000	0.585 oz gold per ton, 27.4 oz silver per ton, 0.07 percent copper, 4.30 percent lead, 5.29 percent zinc, 8.27 percent arsenic, and 1.36 percent antimony.
68	Orphan Boy mine.*	Indicated and inferred, restricted marginal reserve.	30,000	0.550 oz gold per ton, 2.6 oz silver per ton, 0.27 percent copper, 6.67 percent zinc, and 3.81 percent arsenic.
79	Seacrest*----	Inferred, subeconomic---	4,000,000	0.37 percent copper.
		Inferred, subeconomic---	5,000,000	0.20 percent copper, 0.24 percent nickel, and 0.34 percent chromium.
80	New York-Seattle mine.*	Indicated and inferred, subeconomic.	11,000	0.025 oz gold per ton and 1.44 percent copper.
		Inferred, subeconomic---	On the order of 100,000,000.	0.012 oz gold per ton, 0.14 percent copper, and 0.14 percent arsenic.
84	Blue Canyon--	Inferred, subeconomic---	100,000	0.161 oz gold per ton and 5.17 percent arsenic.
103	Daisy mine---	Indicated and inferred, restricted marginal reserve.	1,700,000	0.251 oz gold per ton, 2.1 oz silver per ton, 0.06 percent copper, 0.82 percent lead, 0.77 percent zinc, 3.04 percent arsenic, and 0.04 percent antimony.



EXPLANATION

⚒33 MINE HAVING RESOURCES

≻28 MINE LOCALITY DISCUSSED IN TEXT

•79 DRILL HOLES

Figure 3.—Map showing mining districts and locations of mines discussed in text (after Johnson and others, in press).

head of Silver Creek in May 1873. An arrastra was built to crush and grind gold ore in 1880, but the ores of the district were not free-milling and gravity concentration of ground ore was unsuccessful. Prospecting activity waned until the discovery of the Monte Cristo mining district in 1889. By 1907, the New York-Seattle mine had a mill and tramway operating and the mine produced ore. Production was short-lived and exploration activity did not pick up again until the late 1950's when major companies began exploring for porphyry-copper deposits (Majors and McCollum, 1977). Although exploration activity has been high, production from the district was scant, and the only recorded production came from the New York-Seattle mine outside the roadless area.

Troublesome Creek mining district

The district is in the southwest part of the roadless area. Prospecting began in the district as early as 1874, with the first claims being located in 1889. Exploration and development was greatest between 1890 and 1899. No production has been recorded from the district.

Goat Lake mining district

The district is in the northwest part of the roadless area. Prospecting in the Goat Lake mining district began in July 1891. The Goat Lake Gold Mining Co. and the Mackintosh Mining Co. were organized during the next several years (Majors and McCollum, 1977). Twenty-two claims held by the Mackintosh Mining Co. were sold to a group of investors from Pennsylvania in 1894, and in 1895, the Penn Mining Co. was organized. The company began development work at the Foggy mine (no. 5, fig. 3) in 1897 and work continued through 1906 (Woodhouse, 1979). When the mine was shut down, seven levels with about 10,000 ft of drifts and crosscuts had been developed. No production has been recorded from the Foggy mine or elsewhere in the district.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Resource evaluation of the Glacier Peak Roadless Area is based on previous studies of mineral deposits as well as our concept of ore genesis. Both nonmetallic and metallic resources have been examined; no energy resources were identified.

The classification of mineral resources for known deposits found in the roadless area was made according to the terminology of U.S. Geological Survey Circular 831 (U.S. Bureau of Mines and U.S. Geological Survey, 1980). The classification of mineral potential of an area, however, represents an integration of measurable data and the subjective evaluation of the degree to which those data, and the interpretation of the geologic conditions inferred, represent a known mineral deposit type. We use three terms, "high," "moderate," and "low," to define areas having the potential for mineral resources within the Glacier Peak Roadless Area. An area having a high potential for mineral resources is one in which most of the geologic criteria outlined in applicable mineral deposit models are met. Furthermore, a deposit of that general type and age must exist in the western cordillera. An area having a moderate potential is one in which the geologic criteria permit a particular deposit type, but the geochemical or geophysical evidence for mineralization is less well defined; however, a reasonable chance for the occurrence of concealed mineral deposits exists. All other areas have a low potential either because we do not have sufficient geologic data or understanding to define a mineral deposit model, or because the data do not indicate geologic conditions favorable for ore accumulations. An area of low potential may include areas of concealed mineralization as well as areas of dispersed mineral occurrences.

In evaluating the mineral potential of the roadless area, we summarize our previous studies of the geology, geochemistry, geophysics and mines and prospect evaluations. Two basic, but genetically related hydrothermal deposit types are present in the area: epithermal base- and precious-metal veins associated with intrusive rocks, and a concealed porphyry deposit. The general features of these two classes of deposits are summarized below.

Base- and precious-metal epithermal veins are common peripheral to porphyry deposits. Geologic features of these veins include an association with thick piles of andesite and rhyolite that occur in regions characterized by tensional or extensional regional tectonic patterns. Epithermal vein deposits form near the surface and are near centers of volcanic activity. Geochemical anomalies commonly observed in stream sediments often include arsenic, antimony, silver, gold, tellurium, lead, zinc, and copper. Heavy-mineral concentrates panned from stream sediments often contain arsenopyrite, chalcopyrite, pyrite, galena, sphalerite, scheelite, cinnabar, native gold, and a host of sulfosalt minerals. Widespread sericitic (illitic), kaolinitic (argillic), and propylitic (chloritic) alteration are present in the epithermal environment. Thin envelopes of potassic alteration may occur along vein walls where chalcopyrite is abundant. Brecciation is common. Sulfides are disseminated or deposited in vugs, fractures, veins, and open spaces (Berger, 1982; Berger and Eimon, 1983; Barton, 1982). The deposits found in the Monte Cristo mining district, first studied by Spurr (1901), are an excellent example of epithermal veins.

Porphyry deposits are associated with calc-alkaline igneous rocks that passively intrude regional zones of structural weakness caused by crustal extension or strike-slip faulting. The igneous rocks of the volcanic porphyrys intrude slightly older volcanic rocks of the same composition. Commonly, porphyry deposits are associated with breccia pipes and (or) dike swarms; alteration is widespread. Numerous examples are found in the Canadian cordillera (A. S. Brown, 1976). Hollister (1979) has briefly summarized the distribution of known porphyry-type deposits from the Canadian cordillera south into the Cascade Mountains of Washington and Oregon.

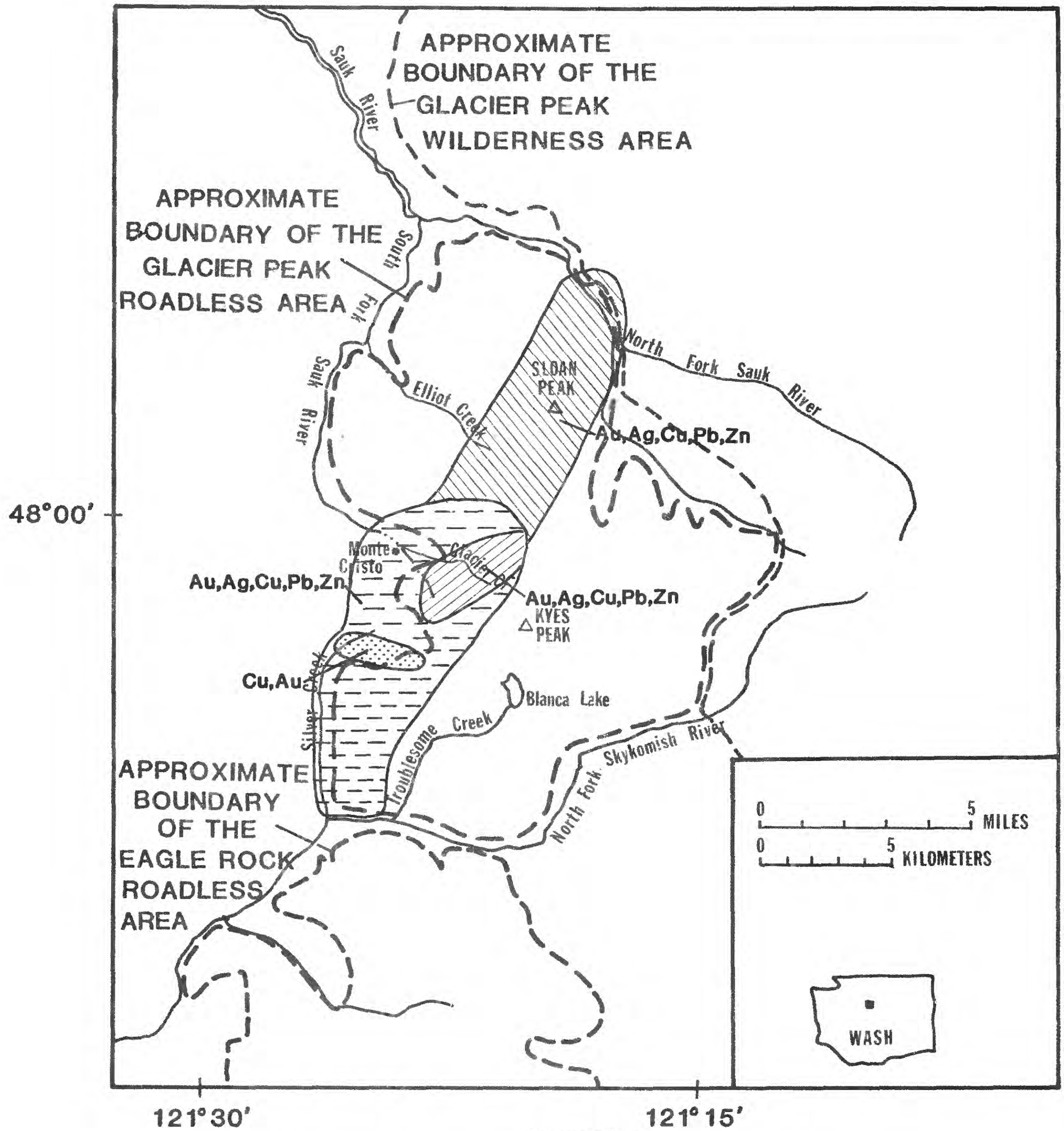
The volcanic-porphyry deposit is generally characterized by argillic, phyllic, and propylitic alteration halos, potassic alteration is rarely exposed, and an intense chlorite halo is common. Alteration of mafic minerals to magnetite may produce a magnetic high associated with the deposit, and base- and precious-metal veins are peripheral associations. Stockwork developed in the volcanic edifice or autobrecciation may indicate a very shallow igneous cupola. Gocd circulation in permeable rocks is needed to form a deposit. Geochemical anomalies may be observed in stream sediments for manganese, copper, molybdenum, lead, zinc, silver, and gold. Heavy-mineral concentrates may contain gold, barite, molybdenite, galena, chalcopyrite, pyrite, bornite, scheelite, and sphalerite. Geochemical anomalies found in the heavy-mineral concentrates may include tungsten, bismuth, barium, tin, and mercury in addition to those given for stream sediments. (See Pilcher and McDougall, 1976; A. S. Brown, 1976; Titley and Beane, 1981; Beane and Titley, 1981; Lowell and Guilbert, 1970; Grant, 1969; Cox, 1982, 1983; Chaffee, 1982a, b; Moss, 1982).

Investigations of the extensive mine workings in the roadless area are covered in Johnson and others (in press). Of the more than 109 properties examined, 20 properties have identified resources (see table 1). The mines and prospects discussed in this text are shown schematically in figure 3. An additional 66 properties, which cannot be shown at the scale of figure 3 may have possible undiscovered base- and precious-metal resources in vein deposits, and three may have possible undiscovered base-metal resources in disseminated deposits (Johnson and others, in press). The potential for base- and precious-metal resources in the Glacier Peak Roadless Area is shown schematically in figure 4.

In the Monte Cristo mining district, the total indicated and inferred gold-silver-copper-lead-zinc resources and restricted reserves are estimated at nearly 51 million tons (table 1, nos. 13-56). Of this total, about 50 million tons are in the large shear zone developed by the Justice, Golden Cord, Mystery, New Discovery, and Pride of the Mountains mines (see figure 4). The zone is exposed either underground or on the surface over a strike length of 5,800 ft. It ranges in width from less than 1 ft to over 20 ft and contains quartz veins and lenses that pinch and swell sporadically along both strike and dip. The veins and lenses contain various amounts of pyrite, pyrrhotite, arsenopyrite, sphalerite, galena, chalcopyrite, stibnite, and lesser amounts of azurite, malachite, boulangerite, realgar, orpiment, and numerous unidentified sulfosalts. The sheared, bleached, limonite-stained country rock bordering the quartz veins contains disseminated sulfide minerals, but metal values are much lower than in the veins. Most of the other deposits in the district resemble this deposit and are different only in scale. Stream-sediment anomalies of copper, cobalt, molybdenum, tungsten, antimony, arsenic, gold, lead, silver, and zinc, are widespread (Church and others, in press). On the basis of our sampling of mineralized structures, Johnson and others (1983) conclude that many of the mines in the district have possible undiscovered resources and that the structural and geologic conditions (Tabor and others, 1982b) are favorable for the occurrence of additional resources. Investigations of the Foggy mine to the north in the Goat Lake mining district and additional mines outside the roadless area to the northwest suggests that the potential for the occurrence of base- and precious-metal resources is less favorable to the northwest of this major shear zone. We classify the bulk of the Monte Cristo mining district as an area of high potential for the occurrence of base- and precious-metal resources in vein deposits and classify the remainder as having a moderate potential. We extend the area of moderate potential northeast into the Goat Lake mining district on the basis of geochemical surveys (Church and others, in press) and mine evaluations (Johnson and others, 1983).

Hydrothermal veins similar to those of the Monte Cristo district occur throughout the Silver Creek mining district. However, vein-type resources in the roadless area were identified only at the Blue Canyon mine (no. 84, fig. 3). On the west side of the Troublesome Creek mining district, the Daisy mine (no. 103, fig. 3) also contains base- and precious-metal resources (see table 1). Mineralogy of the veins include pyrite, chalcopyrite, bornite, arsenopyrite, galena, sphalerite, and minor amounts of free gold. Studies by Ream (1972) indicate the first phase of mineralization was characterized by pyrrhotite, marcasite, and pyrite, the second phase by the more diverse sulfide suite defined above, and the third phase by quartz, calcite, siderite, dolomite, and sulfides. Mineralization is most prominent along major tensional joints (N. 55° E. - N. 85° E. in the northern part of the Silver Creek mining district and N. 75° E. - N. 100° E. in the southern part of the Silver Creek mining district; Ream, 1972, p. 28-31).

In addition to the polymineralic base- and precious-metal sulfide vein deposits, two breccia pipes, and a porphyry-stockwork, all associated with the tonalitic intrusions exposed near the headwaters of Silver Creek were carefully examined. Ream (1972, p. 10) describes the westernmost breccia pipe. It is characterized by extensive shearing, alteration, and sulfide mineralization that fills voids in the breccia. The second breccia was never found in outcrop. Boulders of an intrusive breccia, as much as 10 ft in diameter, occur along Silver Creek for a distance of about 300 ft. This locality was immediately below the Seacrest prospect (no. 79, fig. 3) where more than 4,000 ft of drill core have intersected a low-grade porphyry-copper deposit (see table 1). Exploration of this prospect has been vigorous since the original drilling in 1967-68 with at least ten major exploration companies showing an active interest. The New York-Seattle mine (no. 80, fig. 3), immediately south and west of the drill holes, explores part of a quartz stockwork in tonalite. The tonalite intrudes metasedimentary rock and is exposed only near Silver Creek (see fig. 1) and in an east-trending drainage where the sedimentary rock has been metamorphosed to hornfels. Sulfide minerals and sulfide-bearing quartz veins and veinlets occur in the tonalite along a N. 20° E. and N. 60° W. pattern. The sulfide minerals include chalcopyrite, pyrite, arsenopyrite, and lesser amounts of sphalerite. The deposit appears to be very large and may extend into the roadless area. Copper and gold resources at the New York-Seattle mine (no. 80, fig. 3) are on the order of 100 million tons, but the grade is low, averaging 0.14 percent copper.



EXPLANATION

ZONE OF PROVEN RESERVES FOR BASE AND PRECIOUS METALS

ZONE OF HIGH POTENTIAL FOR THE OCCURRENCE OF PORPHYRY-COPPER RESOURCES

GEOLOGIC TERRANE HAVING HIGH POTENTIAL FOR THE OCCURRENCE OF MINERAL RESOURCES

GEOLOGIC TERRANE HAVING MODERATE POTENTIAL FOR THE OCCURRENCE OF MINERAL RESOURCES

Au Gold

Ag Silver

Cu Copper

Pb Lead

Zn Zinc

Figure 4.—Mineral resource potential map of the Glacier Peak Roadless Area. Areas having both high and moderate potential for the occurrence of base- and precious-metal resources in epithermal veins, and for the occurrence of disseminated porphyry-copper resources are indicated.

Resources at the Seacrest prospect (no. 79, fig. 3) are calculated only for the areas delineated by drilling (4 million tons at 0.37 percent copper and 5 million tons at 0.2 percent copper); actual resources may be much larger. Drilling also intersected an ultramafic body at this location and resources of chromium and nickel from the ultramafic body are shown in table 1. Hydrothermal alteration and mineralization indicative of a porphyry deposit were also observed at the Red Mountain prospect (no. 101) due east in the Troublesome Creek mining district and may reflect an extension of this porphyry deposit into the roadless area. Geochemical anomalies indicative of a porphyry deposit were also found south of Blanca Lake (Church and others, 1982).

Many of the features observed in the field are characteristic of the volcanic-porphyry deposit described earlier. The presence of breccia pipes containing rounded clasts of volcanic rock having sulfide cement, alteration of overlying rocks, particularly sericitic and phyllic alteration, as indicated in the quartz stockwork observed in the New York-Seattle mine (no. 80), and base- and precious-metal hydrothermal veins peripheral to the deposit are all primary features of the volcanic-porphyry deposit. The Silver Creek and the western part of the Troublesome Creek mining districts have high potential for the occurrence of base- and precious-metal resources in hydrothermal veins and for the occurrence of copper and gold resources in large, disseminated porphyry-type deposits.

Sand and gravel deposits occur in the roadless area, but larger deposits exist closer to market areas. Traces of gold occur in the gravels in the Troublesome and Elliott Creek drainages, but grades are so low they are of no economic significance. There is a low potential for the occurrence of placer gold resources. There are no known deposits of coal or oil and gas; a low potential for the occurrence of energy resources is indicated.

Mineral resources identified at 16 properties in the Glacier Peak Roadless Area total nearly 53 million tons. Of this total, nearly 47 million tons are classified as restricted marginal reserves; these resources are restricted because of current environmental regulations on production and disposal of arsenic-bearing materials. Another 110 million tons of resources, mostly in low-grade porphyry-copper stockworks occur in four deposits adjacent to the roadless area and may extend into it.

All of the resources in the roadless area occur in shear zones ranging from less than 1 ft to as much as 20 ft thick. Although the zones pinch and swell, they appear to be persistent along strike. One major mineralized zone is exposed for over a mile along strike. Quartz veins and lenses in the shear zones contain most of the metal values, and also pinch and swell sporadically along strike and dip. Furthermore, gold and silver values in the quartz differ greatly along strike and dip; locally high values occur in ore shoots. Most of the stopes in the mines represent those areas that formerly contained high grade shoots. For the purposes of calculation of ore reserves (see table 1), this mineralized zone (see fig. 4) has been divided into an upper and a lower block. The lower block is relatively deep in the deposit and has been less thoroughly explored. The level of confidence of the resource estimate for the lower block is not as high as that for the upper block which has been developed by previous mining activity.

Two mining methods could probably be used for these deposits: (1) The shrinkage stoping method could be used where the shear zone is over 4 ft thick and where the back and walls will stand well. In this method, ore is mined in successive slices, working upward from each level; all material, ore and waste, in the mined thickness is broken and removed together. The large zone in the Monte Cristo district probably is amenable to this method. Mining this zone would cost at least $32 per ton. (2) The resuing method could be used at those deposits with thin, high-grade veins. In this method, wall rock (waste) on one side of the vein is removed before ore is broken; there is less dilution of the ore with this method. As in the shrinkage stope method, both the walls and back would have to stand well. Resuing works best where the ore is not "frozen" to the walls, and there is considerable difference between the hardness of the ore and the wall rock (Gardner and Jackson, 1937). Cost per ton of ore removed by this method would be considerably higher than that for the shrinkage stoping method, and would depend on the vein thickness.

Beneficiation of the resources would be unusually difficult because of the complex mineralogy of the ore. Mine-run ore would contain various amounts of pyrite, pyrrhotite, arsenopyrite, chalcopyrite, sphalerite, galena, stibnite, and lesser amounts of azurite, malachite, boulangerite, realgar, orpiment, and other sulfosalts, all in a gangue of quartz and sheared country rock.

Because of the complexity of the ore, only the gold, silver, lead, and zinc would probably be recovered. The process might include: grinding the ore, then, by flotation, making a lead concentrate containing gold and silver. Tailings from the lead float would go to a zinc flotation circuit; the zinc concentrate would also contain gold and silver. Lead and zinc concentrates and tailings from the zinc circuit would go to separate hearth roasters to remove arsenic. Lead and zinc concentrates would then be sent to a smelter to recover lead, zinc, gold, and silver. Material from the zinc circuit tailings roaster would be treated with a cyanide leach solution to recover gold and silver. Metal recovery is estimated at 80 percent for lead and zinc and 70 percent for gold and silver. The cost for milling mine-run ore, using the above process, would probably be at least $22 per ton for a 2,000-ton-per-day mill.

Based on estimates using 1983 costs, total development, mining, milling, smelting, and other production costs would probably total about $70 per ton of ore for large, thick deposits amenable to shrinkage stoping; costs would be considerably higher for smaller deposits.

It should be emphasized that the above beneficiation process is greatly simplified, and the recoveries and costs are only estimates. Exhaustive testing is required to determine the best recovery process for the smallest investment. Arsenic in ores is extremely detrimental; large amounts of arsenic oxides would be produced in the process outlined in this report. If the arsenic concentrates cannot be sold, there could be problems with their disposal.

The U.S. Bureau of Mines Research Center in Reno, Nev., is currently developing a chlorine-oxygen leaching process for complex sulfide concentrates that contain a variety of metal sulfides including arsenic and antimony sulfides. A similar process is in commercial operation at the Equity Silver Mines Ltd. in Houston, British Columbia, where gold and silver are being removed from arsenic- and antimony-bearing sulfosalt ores. Further research is necessary, however, before an ore processing circuit can be designed for the arsenopyrite ores. No market has been found for the calcium arsenate byproduct from this process.

Two deposits in the Silver Creek mining district, just outside the roadless area, contain very large, low-grade copper resources. The Seacrest, a porphyry-type deposit, and the New York-Seattle, a stockwork deposit, are large enough to employ lower-cost open-pit or sub-level-caving mining methods. The method used would depend on the shape and orientation of the ore body.

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