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MISCELLANEOUS FIELD STUDIES
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PAMPHLET

MINERAL RESOURCE POTENTIAL OF THE GLACIER PEAK WILDERNESS AND ADJACENT AREAS, CHELAN, SKAGIT, AND SNOHOMISH COUNTIES, WASHINGTON

By

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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 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 Glacier Peak Wilderness (NF031), Mount Baker-Snoqualmie and Wenatchee National Forests, Chelan, Skagit, and Snohomish Counties, Wash. The area was established as a wilderness by Public Law 88-577, September 3, 1964. The study area also includes eight areas classified as proposed wilderness (06031A, D, G) during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January 1979, and one area (06031C) proposed as an administrative addition.

MINERAL RESOURCE POTENTIAL SUMMARY

Geologic, geochemical, geophysical, and mine and prospect surveys were conducted in 1976-82 to evaluate the potential for mineral resources in the Glacier Peak Wilderness and proposed additions. Eleven areas, covering about 20 percent of the study area, have a moderate to high potential for the occurrence of base- and precious-metal resources. Six properties, two of which are in areas recommended for wilderness addition (06031D and G), contain demonstrated resources for copper, lead, zinc, gold, and silver. The most important demonstrated resource is the porphyry copper-molybdenum deposit at the Glacier Peak prospect, near the center of the wilderness, where drilling has delimited a deposit totaling 1.9 billion tons of mineralized rock. Although porphyry copper-molybdenum deposits are the primary type of deposit that occurs in the study area, areas of potential for the occurrence of precious-metal resources in hot-springs deposits, for the occurrence of base- and precious-metal resources in hydrothermal veins and limestone-replacement deposits, and for the occurrence of copper, zinc, gold, and silver resources in volcanogenic massive-sulfide deposits have also been identified.

At 1983 metal prices, none of the mineral deposits in the study area would be mineable; however, at historically high metal prices, portions of the Glacier Peak prospect would be mineable by underground, bulk-mining methods. In addition, the Pioneer property would be mineable, if the inferred reserves are proven, even with dilution due to the narrow vein width. Metal prices substantially higher would be required to cause the Holden and Royal Development mines to be reopened, although additional exploration, particularly at the latter mine, could change the economics of the properties.

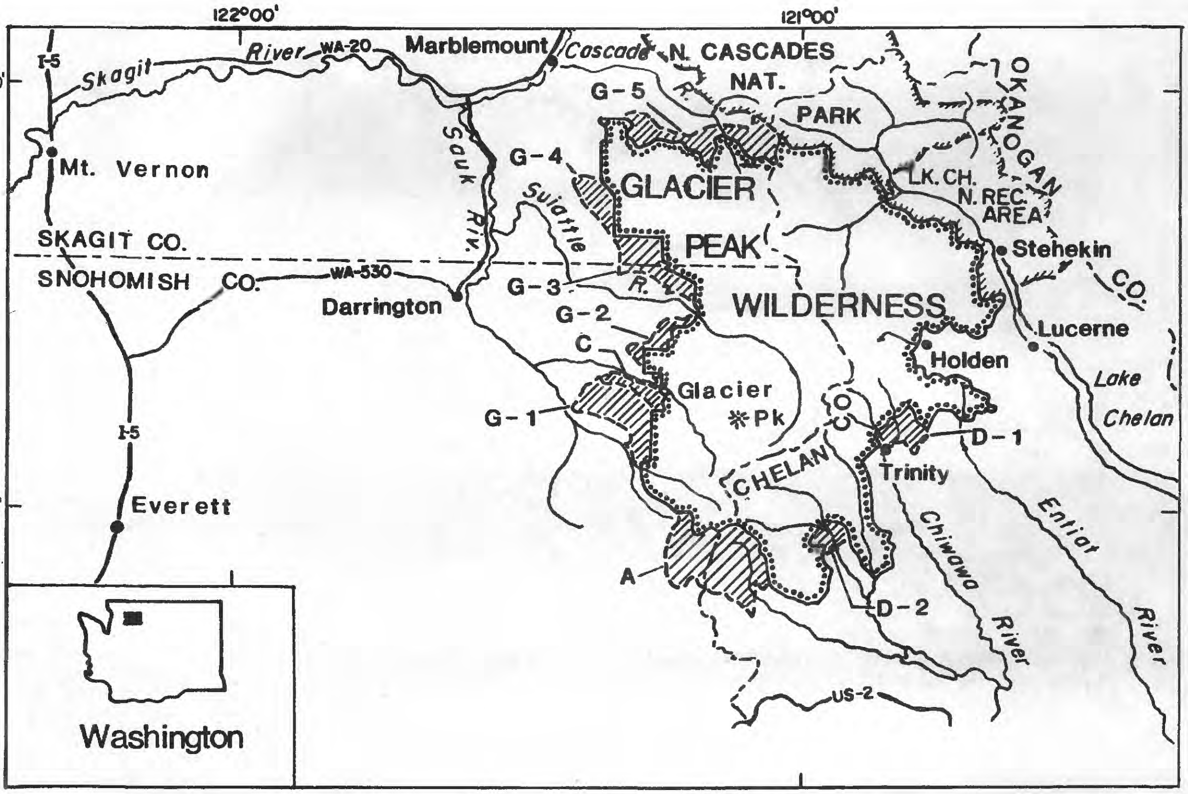
A low potential for geothermal resources exists on the northeast side of the Glacier Peak volcano, and a cinder resource of 24 million cubic yards is identified at the White Chuck cinder cone, in the wilderness. Because both areas are remote, no reserves were identified. No fossil-fuel resources were identified in the study area.

INTRODUCTION

Location, access, and geographic setting

The Glacier Peak Wilderness encompasses 464,741 acres, including 483 acres of patented mining and millsite claims. Also included in the present study are nine areas adjoining the wilderness (fig. 1) that total 90,034 acres of recommended wilderness additions. All these lands are here collectively called the "study area." Access to the study area is provided by generally well-maintained trails from gravel or dirt roads along major valleys above Darrington, Marblemount, Stehekin, Holden, Trinity, and Lake Wenatchee. Other than the main access trails across a few passes (Cloudy Pass, Buck Creek Pass, White Pass, and Indian Pass), trails are rough, infrequently maintained, or nonexistent.

The Glacier Peak Wilderness extends southward about 40 mi along the crest of the northern Cascade



0 — 20 MILES

0 — 30 KILOMETERS

EXPLANATION

Boundary of wilderness

Areas recommended for addition to wilderness

Figure 1.--Map showing location of the Glacier Peak Wilderness and adjacent areas, Chelan, Skagit, and Snohomish Counties, Wash. Areas recommended for addition to the Glacier Peak Wilderness are designated by letters: A, area 06031A; C, area 06031C; D, two areas making up addition 06031D; and G, five areas making up addition 06031G.

Range, Wash., from the southern border of North Cascades National Park. It consists of rugged, highly varied, mostly alpine terrain cut by numerous deep river valleys and dominated by the volcanic cone of Glacier Peak (10,541 ft), rising 3,000-4,000 ft above most nearby summits. Though now dormant, Glacier Peak has been one of the most active Cascade volcanoes in the past few thousand years, with minor activity as recent as the 18th century. The Cascade crest is the drainage divide for waters flowing westward into Puget Sound and eastward into the Columbia River, and it also forms a climatic barrier. Dense fern, low deciduous brush, and forests of Douglas fir, western hemlock, and red cedar dominate the rain forests of the western valleys in sharp contrast with more open forests of larch and pine on eastern slopes. Small glaciers and permanent snowfields cover extensive areas along and west of the crest but are rare to the east. The area west of the Cascade crest is in the Mount Baker-Snoqualmie National Forest, and the area to the east is in the Wenatchee National Forest.

Present and previous studies

Evaluation of the potential for mineral resources in the Glacier Peak Wilderness and adjoining areas of wilderness recommendation (fig. 1) was carried out by the U.S. Bureau of Mines in 1976-79 and by the U.S. Geological Survey in 1979-82. Work by the U.S. Bureau of Mines consisted of sampling, mapping, and evaluating known mineral deposits and occurrences (Stotelmeyer and others, 1982) and reviewing county and U.S. Bureau of Land Management mining-claim records. More than 1,300 lode claims and a few placer claims in the Glacier Peak Wilderness and more than 300 lode claims in adjacent areas recommended for wilderness addition have been located since prospecting of the region began in the late 1800's. Work by the U.S. Geological Survey involved three separate, but coordinated, lines of investigation: (1) geologic mapping and collection of bedrock samples (Ford and others, in press); (2) stream-sediment geochemical surveys (Church and others, 1982); and (3) geophysical surveys using aeromagnetic methods (Flanigan and others, 1983) and gravity methods (Sherrard and Flanigan, 1983). Results of extensive mineral exploration programs in and near the study area by Bear Creek Mining Co. (Spokane, Wash.) were made available for the present study (Grant, 1982). Work by many others, obtained from the extensive literature on the geology and mineral resources of the area (Ford, 1983), was also incorporated in the study.

Geologic setting

The study area, in the south-central part of the north Cascades, consists of a terrane of crystalline rocks of great variety and structural complexity (Misch, 1966) that extends from near Stevens Pass (U.S. Highway 2) northward into British Columbia and from the western foothills of the Cascades eastward to near the Methow Valley and the Okanogan Range. Within this terrane, sedimentary and igneous rocks of early Paleozoic, or older, to Mesozoic age were transformed into schists and gneisses during one or more phases of regional metamorphism, the latest occurring near the end of the Mesozoic Era. Many intrusions of granitic, dioritic, and gabbroic rock were affected by the metamorphism; some had been emplaced prior to metamorphism but others probably were intruded during metamorphism. Most of the country rocks were intensely deformed during metamorphism. Following metamorphism, fault troughs (grabens) and basins developed and were filled with sediments eroded from nearby highlands; the Chiwaukum graben of early Tertiary age lies just south of the eastern part of the Glacier Peak Wilderness, and the eastern bounding fault (Entiat fault) of the graben extends northwestward to form a major structural feature within the wilderness. Another of the Cascades major faults, the Straight Creek fault, also of early Tertiary(?) age but of transcurrent type, lies along the west margin of the wilderness and separates schist and gneiss of high metamorphic rank from metavolcanic and metasedimentary rocks of low metamorphic rank to the west. Widespread granitic intrusive activity continued through the early Tertiary to Miocene time. Miocene granitic magmas intruded to very shallow crustal levels, and some may have reached the surface as lavas. The Cascades were uplifted and deeply dissected by erosion prior to building of andesitic to dacitic volcanic cones, such as Glacier Peak and Mount Baker, in Quaternary time.

Mining activity

All or parts of five mining districts are within the study area (fig. 2). The Stehekin, Railroad Creek (Holden), and Chiwawa districts are on the east side of the wilderness; part of the Cascade mining district is in the northern part of the study area; and the Sampson district is near the center of the wilderness. Since 1891, about 1,600 lode claims have been located in the study area. Additional large claim blocks were staked periodically to cover the deposit at the Glacier Peak prospect.

The earliest known mining claims recorded in the study area apparently were located in 1891 at the head of the South Fork of Agnes Creek and on the divide between the Little Wenatchee River and the North Fork of the Sauk River. Surveyers searching for a railroad route over the Cascade Range noted mineralized areas on Railroad Creek in 1887, and J. H. Holden prospected the area in 1892. In 1896, he staked what later became the Holden mine, Washington's largest copper mine, which operated from 1938 to 1957. Farther up the canyon, the Crown Point molybdenum deposit was probably discovered in 1897 or 1898, and a mill and mine camp were constructed.

Other early claim locations in the study area were made during 1892 on Flat Creek in the northwest corner of the wilderness and on a mineralized area, later to be patented, which was located on the Middle Fork of the Cascade River, in area 06031G. Discoveries were also made south of Trinity in the Chiwawa River drainage basin, and the Royal Development (Red Mountain) mine in area 06031D was probably discovered after the turn of the century.

The Glacier Peak prospect, the most significant mineral deposit in the study area, was first located as a vein occurrence about 1900 by Sampson Mining Co. Early exploration of the property was by short adits following copper-rich shear zones. Later exploration utilized diamond drilling and revealed a huge disseminated porphyry copper-molybdenum deposit.

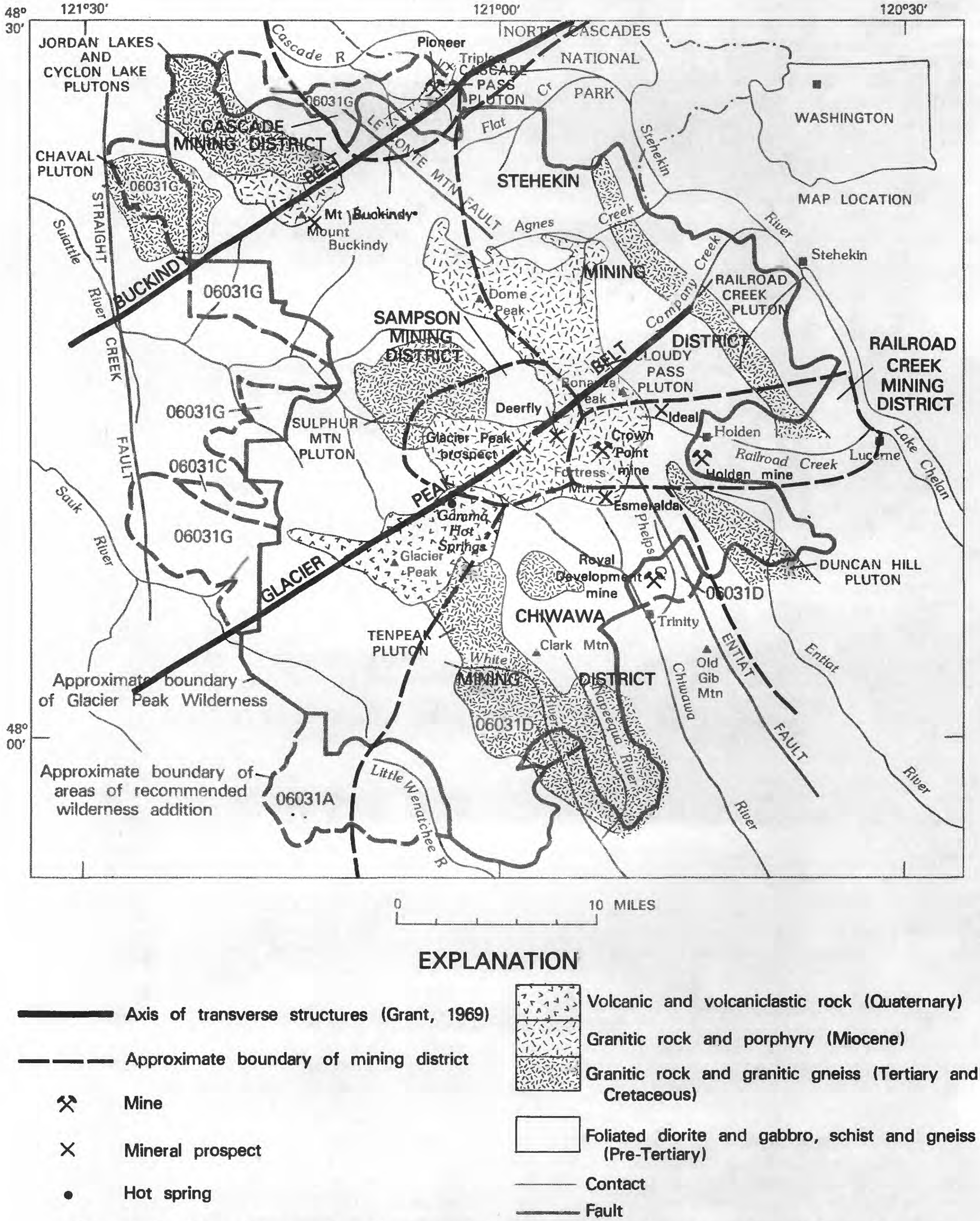


Figure 2.--Map showing location of mining districts and major mineral deposits and their relation to the regional structural belts defined by Grant (1969).

Bear Creek Mining Co., the exploration subsidiary of Kennecott, completed confirmation drilling in 1959, although additional exploration and patent application holes were drilled as late as 1970.

ACKNOWLEDGMENTS

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GEOLOGY, GEOCHEMISTRY, AND GEOPHYSICS PERTAINING TO MINERAL RESOURCE ASSESSMENT

Geology

The Glacier Peak study area transects the crystalline core of the north Cascades, a structurally complex and highly varied metamorphic and plutonic terrane of Mesozoic and older units (Misch, 1966, 1977). These units were extensively intruded by Tertiary granitic plutons, some as young as Miocene. The study area occupies a southward projection of the area of copper-molybdenum porphyry deposits of predominantly Tertiary age in the Canadian cordillera (Christopher and Carter, 1976). Among the numerous prospects, mineral occurrences, and deposits of varied type known in the study area (Grant, 1982; Stotelmeyer and others, 1982), the most important deposits are the porphyry-copper type accompanied by peripheral hydrothermal veins associated with granitic rocks and porphyritic phases of shallow-level Miocene plutons.

Two principal episodes of major, medium- to high-rank regional metamorphism affected the sedimentary and igneous rocks of this part of the north Cascades (Misch, 1966, 1977). One metamorphic event occurred about 415 m.y. ago in the early Paleozoic, and the other about 60-90 m.y. ago near the end of the Cretaceous (Mattinson, 1972). Original ages of pre-Upper Cretaceous rocks are, in general, poorly known because of extensive resetting of mineral ages by the younger metamorphism. Mattinson's (1972) uranium-lead ages from zircons of about 220 m.y. for the Marblemount Meta-Quartz Diorite of Misch (1966) and the Dumbell Mountain plutons of Cater and Crowder (1967) show that granitic intrusive activity began at least as early as the Triassic. These bodies form a northwest-trending central belt in the study area (unit pTqd), extending from the Cascade River in the north to east of Trinity. Extensive intrusive activity also occurred about 90 m.y. ago in the Late Cretaceous, according to Mattinson's (1972) uranium-lead ages for the Eldorado Orthogneiss of Misch (1966) and potassium-argon and uranium-lead ages reported by Tabor and others (1980, 1982) for the Tenpeak pluton and Sloan Creek plutons. Two large plutons of dioritic, quartz dioritic, and tonalitic to gabbroic composition (Chaval and Riddle Peaks plutons) are undated, but their involvement in regional metamorphism also suggests a pre-Tertiary age. Numerous radiometric ages show that major granitic intrusive activity continued through the early Tertiary (Railroad Creek and Duncan Hill plutons and other smaller ones) and into the Miocene (Cloudy Pass and Buckindy plutons and related smaller bodies). Sulfide mineralization is chiefly associated with the Miocene plutons and, to a lesser extent, with the Riddle Peaks and possibly a few other plutons. Many large plutons, including the Tenpeak, Sloan Creek, Sulphur Mountain, High Pass, Jordan Lakes, Chaval, Cyclone Lake, Downey Creek, and Railroad Creek plutons, show little or no evidence of associated hydrothermal mineralization.

Numerous, mostly high-angle, faults occur in the study area, but two of regional magnitude are dominant: the Entiat fault in the interior and the Straight Creek fault near the west margin of the study area. The Entiat fault extends from the study area at least 30 mi southeastward to near Wenatchee, where it forms the east-bounding fault of the Chiwaukum graben. To the north, in the study area, the Entiat fault was intruded by the Cloudy Pass pluton. In pre-Miocene time, the Entiat fault probably continued north of the Cloudy Pass pluton as the LeConte Mountain fault. The Straight Creek fault, which is a probable strike-slip fault, is cut by a Miocene pluton (Grotto batholith) and extends northward and southward beyond the limits of the study area (Misch, 1966, 1977; Tabor and others, 1982). Many mineral properties and occurrences are near the Entiat fault, but none occur near the Straight Creek fault within the study area.

The distribution of prospects, deposits, and known mineral occurrences described by Grant (1982) and Stotelmeyer and others (1982) shows a marked concentration in the east-central part of the wilderness, northeastward from a line approximately along the Chiwawa River, through Glacier Peak prospect to the Mount Buckindy area. In that sector, many mineral properties are in or near two of Grant's (1969) mineralized "transverse structural" belts, or lineaments (see fig. 2). The belts trend northeastward across the dominant northwest-trending structural grain and are characterized by closely spaced subvertical joints, en-echelon fractures, and shears that Grant (1969) considered to be high-level expressions of deep crustal movement.

Many mineral properties and prospects in the study area are in the Buckindy belt. These include the Mount Buckindy, Milt Creek, Michigan, Skagit, Pioneer (Epoch), and Grand Republic properties (Stotelmeyer and others, 1982), of which the most significant are the Mount Buckindy and Pioneer. Mineral properties that are in the Glacier Peak belt include the Glacier Peak porphyry copper-molybdenum deposit along Miners Ridge, the Deerfly, Fortress Mountain, Esmeralda, and Copper Point prospects, and the Crown Point mine. These properties and prospects occur in or near the youngest dated (Miocene) plutons of calc-alkaline tonalite, granodiorite, and some granite; properties in the Buckindy belt are associated with the Buckindy pluton and the Cascade Pass dike of Tabor (1963), and properties in the Glacier Peak belt are associated with the Cloudy Pass pluton. Porphyry copper-molybdenum deposits occur in hosts of similar type in the Canadian cordillera, where metallogenic epochs of the porphyry-ore formation are dated at 200-195 m.y., 185-175 m.y., 155-140 m.y., 80-65 m.y., 50 m.y., 40-35 m.y., and 26-18 m.y. in age (Christopher and Carter, 1976). Potassium-argon ages of the Buckindy pluton (R. J. Fleck, written commun., 1982), Cascade Pass pluton (Engels and others, 1976; and R. J. Fleck, written commun., 1982), Cloudy Pass pluton (Tabor and Crowder, 1969), and of granodiorite from the Royal Development mine(?) (Engels and others, 1976) are within or near the youngest episode of the Canadian mineralization. Other, generally undated, small bodies of porphyry occur widely through mainly the eastern part of the study area. The plug at Old Gibb Mountain yielded an older age of 43.9 m.y. (Cater and Crowder, 1967), indicating a considerable age span for intrusive activity. However, though undated, many small bodies of porphyry are believed to be related to the larger plutons dated as Miocene, including many around the periphery of the Cloudy Pass pluton that are too small to delineate at 1:100,000 scale. Some of these satellite plutons are, or appear to be, related to known mineral occurrences in the wilderness between Phelps Creek and the Chiwawa River.

Large areas of both the Buckindy and Cloudy Pass plutons appear barren of significant sulfide mineralization. Both are shallow-level intrusions containing breccias that suggest explosive venting of late-stage, volatile-rich fluids. Intrusive breccias are particularly common in and near the southern and eastern parts of the Cloudy Pass pluton (Cater, 1969); they also occur in the northern parts of the pluton (Grant, 1966). Numerous masses of sulfide-bearing and altered breccia on Phelps Ridge, located in the wilderness between Phelps Creek and the Chiwawa River, are closely associated with porphyry plugs that are probably related to the Cloudy Pass pluton (Cater, 1969). Distribution of these breccias and the 24.5 m.y. age of granodiorite at Trinity (Engels and others, 1976) strongly suggest that the Cloudy Pass pluton underlies the Swakane Biotite Gneiss along Phelps Ridge. Pipelike bodies of intrusive breccia associated with porphyry plugs cut biotite gneiss in the roof of the Buckindy pluton at Mount Buckindy. Breccias of probable explosive origin also occur near the roof of the Cascade Pass dike, an apparent northeastward extension of the Buckindy pluton. The slightly different ages of the Cascade Pass pluton (18 m.y., Engels and others, 1976) and the Buckindy pluton (15 m.y., R. J. Fleck, written commun., 1982) indicate that they may be separate intrusions. Most areas of significant mineralization, including the Glacier Peak deposit on Miners Ridge, properties on Phelps Ridge, and the Pioneer and Mount Buckindy properties, occur in granitic rock, porphyry, or country rock near the roof of intrusive bodies. Deeply eroded parts of the plutons generally appear barren of mineralization.

Venting of the Miocene magma chambers may have included the eruption of magma forming the volcanic deposits of Gamma Ridge (Tabor and Crowder, 1969). Although they have not been dated, small bodies of volcanic rocks near Ross Pass, on northern Lyall Ridge, near Round Lake, and elsewhere may be of similar origin.

Although the dominant mineralization of porphyry copper-molybdenum type known in the study area was clearly related to the Miocene plutonism, other types of mineral deposits may be related to earlier igneous or, possibly, metamorphic events. The deposit at the Holden mine, for example, occurs in a belt of schist and gneiss that extends through the east-central part of the study area. The deposit shows no conclusive relation to plutons in the vicinity and is considered by DuBois (1954) to be related to high-rank regional metamorphism. A gangue mineral from the mine, phlogopite, gave an age of 44.1 m.y. (Engels and others, 1976), which is younger than the latest regional metamorphism in Cretaceous time, but older than the Miocene plutonic events that formed the Glacier Peak deposit. The deposit is near the north end of the Duncan Hill pluton (Cater, 1982), which has yielded potassium-argon ages in the range of 46-43 m.y. (Engels and others, 1976), spanning the age of the Holden gangue. This age equivalence may reflect thermal resetting of the phlogopite by contact metamorphism rather than showing a direct relation of the Holden deposit to the Duncan Hill pluton.

The Riddle Peaks pluton is mostly hornblende-bearing, layered gabbro (Cater, 1982) and contains five small claims in oxidized and mineralized rock. Disseminated sulfide and iron-titanium oxide minerals are common in the gabbro, but concentrations of more than a few modal percent have not been found. Bodies of this type may contain inconspicuous but significant amounts of platinum-group metals, commonly in small segregations that are difficult or impossible to identify without more detailed geochemical and microscopic studies. Chromite lenses, a common igneous association in other layered gabbroic plutons, have not been identified in this pluton. Finally, numerous, mostly small, bodies of metaperidotite or other ultramafic rocks, some of which contain prospects, are widely scattered in a central schist belt in the study area.

Geochemistry

A geochemical survey was made during the summers of 1979 and 1980. Collection of stream sediments, supplemented by heavy-mineral-concentrate samples panned from stream sediments, constituted the reconnaissance phase of the investigation. Samples were collected primarily from first-order-stream drainage basins representing areas of 1-2 mi^2, although some represent larger drainage basins. The minus-80-mesh fraction (<177 micrometer) of the stream-sediment samples was separated for analysis.

Emission spectrography was used for most of the analytical work (Church and others, 1982, 1983a), although a new method, a partial digestion in aqua regia followed by analysis using an Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP), was also applied to the stream sediments (Church and others, 1983c). Mineralogical studies (Church and others, 1982, 1983a) were made of the nonmagnetic heavy-mineral concentrates collected in 1980. Representative suites of rock samples were collected from each major formation and were analyzed to determine thresholds for each of the geologic terranes (S. E. Church, unpub. data, 1983). Studies of altered zones not previously defined (Grant, 1982), as well as detailed sampling of mineralized areas, were used to define elemental suites indicative of mineralization. Anomalous elemental concentrations in stream sediments were defined from these data. The suite comprising copper, molybdenum, tungsten, gold, cobalt, lead, zinc, and silver is associated with the porphyry-copper mineralization at the Glacier Peak deposit and is a common association for porphyry-copper systems in the Canadian cordillera (Pilcher and McDougall, 1976). The suites comprising lead, silver, and zinc; lead, arsenic, and antimony; and lead, silver, and molybdenum are found in the northeastern part of the study area and represent base-metal and precious-metal hydrothermal systems.

Geophysics

Data obtained from an aeromagnetic survey flown specifically for this study were added to existing data (Flanigan and others, 1983); the magnetic data were collected along northeast-southwest flight lines spaced 0.5 mi and 1.0 mi apart at 1,000 ft terrain clearance.

Several of the magnetic features seen in the composite aeromagnetic data may be associated with geologic features, some of which may be important indicators of mineralization. A regional belt of magnetic anomalies, both highs and lows, that trends north-northwest across the northeast part of the study area is associated with a belt of plutonic and metamorphic rocks along the Entiat fault. Major transverse structural zones trending N. 30°-90° E. are reflected by the northeast alinement of magnetic anomalies associated with the Mount Buckindy and Cascade Pass plutons (Grant, 1969). These anomalies define the Buckindy belt. An east-west magnetic low, within the magnetic high defined by the Cloudy Pass pluton, crosses the southern part of the pluton near the Glacier Peak deposit and extends eastward beyond Holden. This magnetic signature characterizes mineralization within the Cloudy Pass pluton and is coincident with the Glacier Peak transverse structural belt. Many local magnetic anomalies ranging from a few tens to several hundred gammas can be spatially related to plutonic rocks mapped at the surface.

Known mineral deposits in the study area show three types of spatial relationships with the magnetic anomalies. One group of prospects seems to be spatially related to northwest-trending magnetic lineaments or linear zones of steep magnetic gradient; the Holden mine is a good example. A second group of prospects seems to be spatially related to the outer perimeter, or flanks, of magnetic anomalies associated with some of the Cretaceous and younger plutons such as Riddle Peaks and Mount Buckindy plutons. The Mount Buckindy and Milt Creek prospects are typical of this second class. The third group of prospects is along the east-west magnetic low that parallels the axis of the Cloudy Pass pluton; the Glacier Peak, Deerfly, and Fortress Mountain prospects are the most significant of this group.

MINING DISTRICTS AND MINERALIZATION

U.S. Bureau of Mines personnel examined mines, prospects, and claims in and near the study area (Stotelmeyer and others, 1982). More than 100 sites were examined during the study, and 890 lode samples were taken from mine and prospect workings, outcrops, stockpiles, and dumps (data on file at the U.S. Bureau of Mines, Western Field Operations Center, Spokane, Wash.). Our investigations indicate that the study area is relatively unexplored for minerals. Until recently, a combination of geographical and geological factors adversely affected prospecting and exploration: the harsh environment no doubt was one of the factors, but the lack of bonanza-type oxide and secondary mineralization, resulting from recent glaciation and rapid erosion, discouraged early prospectors. In more recent years, large companies capable of financing exploration for huge, low-grade primary deposits in the igneous rock, or of delineating the erratic occurrences of the rich, pod-shaped sulfide deposits in the metamorphic rock requiring detailed geophysical studies, have been excluded from the area because of environmental constraints.

Results of our mine and prospect evaluation are briefly summarized below for each mining district (fig. 2). Properties having identified metallic resources are listed in table 1, and mines and prospects having possible undiscovered metallic resources are described in table 2. Numbered property locations are from the mines and prospects report by Stotelmeyer and others (in press), who also described other properties examined during the study. There is no current mining activity in the study area.

Sampson district

The Sampson district, in Snohomish County immediately west of the Cascade Range crest, is the most important mining district in the study area. This small district in the center of the wilderness contains only two properties; it is accessible only by trail or helicopter. In the early 1940's, the Glacier Peak deposit was recognized as a low-grade, large-volume porphyry-copper deposit. It is characterized by disseminated and stockwork copper and molybdenum mineralization. A smaller, but similar, deposit of this type may underlie Fortress Mountain about 2 mi southeast of the Glacier Peak prospect where granitic rocks have also intruded gneiss host rock. The Deerfly prospect, a peripheral precious-metal vein deposit, contains indicated and inferred resources of silver, gold, and copper (table 1). The district has had no mineral production and is currently inactive. Eighteen patented claims, consisting of 360 acres in the Suiattle River drainage basin, cover the Glacier Peak deposit.

Chiwawa district

The Chiwawa district includes the Chiwawa, White, Napeequa, and Little Wenatchee River drainage basins. Formerly, the districts were part of the much larger Leavenworth mining district. Access is by all-weather roads, and the main mining and mineralized areas in the study area are relatively accessible by trail.

The Royal Development, or Red Mountain, mine is in area 06031D. The ore occurs in a mineralized breccia pipe at or near the contact of granitic and metamorphic rocks. Copper, silver, and gold were produced between 1929 and 1940, and the total output was about 18,000 tons of ore, from which about 215,000 lbs of copper, 17,000 oz of silver, and 29 oz of gold were recovered. Active exploration was underway in 1981 at this property. Seventy-four claims of the 142-claim group at the Royal Development mine extend into the wilderness. Thirty-eight claims in the group are in area 06031D, nine of which are patented (180 acres); the rest of the claims in this group are adjacent to area 06031D.

Elsewhere in the district, there is evidence for a porphyry copper-molybdenum deposit or a breccia-pipe deposit (Esmeralda property) to the north, along Phelps Ridge within the wilderness. There are six patented claims and one mill site in the wilderness along Phelps Creek.

Production records also suggest that about 7,000 tons of pumice may have been produced between 1943 and 1947 from a small open pit southeast of the Royal Development mine.

Railroad Creek district

Railroad Creek drains part of the eastern portion of the Glacier Peak Wilderness and empties into Lake Chelan. Between 1938 and 1957, the Holden mine produced about 10 million tons of ore that yielded more than 212 million lbs of copper, 40 million lbs of zinc, 2 million oz of silver, and 600,000 oz of gold. The wilderness boundary is at the western edge of the Holden townsite. All material, supplies, and personnel for the Holden mine were brought 45 mi by barge from Chelan or flown in by float plane to Lucerne and then trucked 12 mi to the mine site. A shuttle bus is presently operated between Lucerne and Holden, which is now a church camp.

Recorded mineral production from within the wilderness is molybdenum ore from the Crown Point mine on upper Railroad Creek. Output was reported to be 10-12 tons in 1901-02, and small amounts of ore were also produced between 1903 and 1917.

Currently, there is one claim on a silver-bearing quartz vein (Ideal prospect, fig. 2) in the wilderness, on the east side of Bonanza Peak.

Stehekin district

The Stehekin mining district lies principally northeast of the Glacier Peak Wilderness. Only the part southwest of the Stehekin River is in the study area, and there has been no mining in this part of the district. This area has been little explored for minerals despite the intensity of mineralization, probably because of the difficult access.

Cascade district

About half the Cascade mining district is in the study area; the rest is in North Cascades National Park. Only the section containing the Middle Fork of the Cascade River and the lower part of the South Fork of the Cascade River was studied. The district contains the Pioneer patented claim group (9 claims, 179 acres). Indicated and inferred silver, lead, and zinc resources occur in a hydrothermal vein deposit in area 06031G. Also at the north end of the wilderness, the patented claim group of the Johannasburg mine extends into area 06031G. A small amount of high-grade lead-silver ore was produced in 1953 and 1955, most likely from that part of the claim group inside North Cascades National Park.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Three types of commodities have been examined in the mineral resource evaluation of the study area: metallic resources, nonmetallic resources, and energy resources.

The classification of mineral resources for known deposits found in the study area was made using the terminology of U.S. Geological Survey "Circular 831" (U.S. Bureau of Mines and U.S. Geological Survey, 1980). The classification of the 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 describe the potential for mineral resources of certain areas within the study 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 in which the geochemical or geophysical evidence for mineralization is less well defined; however, a reasonable chance for the occurrence of concealed mineral deposits exists. An area having a low potential is one for which the data do not indicate geologic conditions favorable for ore accumulations. Some areas of low potential are tentatively classified as such on the basis of limited data. An area of low potential may include areas of concealed mineralized rock as well as areas of dispersed mineral occurrences.

Potential for metallic mineral resources

In the evaluation of metallic resources of the study area, we draw heavily on previous studies of mineralization and on our collective experience and

Table 1.--Mines and prospects with estimated metallic resources in the Glacier Peak Wilderness and adjacent areas, Chelan, Skagit, and Snohomish Counties, Washington

[Underlined names refer to properties having a high probability for undiscovered resources]

No. on map[1]	Property	Type	Tonnage (except where noted)	Resource classification[2]	Commodity	Grade
			Sampson mining district			
48	Glacier Peak prospect.	Disseminated copper-molybdenum.	1.9 billion	Total identified resource.	Copper-------------- Molybdenum disulfide	0.334 percent 0.15-0.02 percent
			41.3 million	Measured restricted reserve.	Copper-------------- Molybdenum disulfide Gold---------------- Silver-------------- Tungsten trioxide---	0.71 percent 0.046 percent 0.015 oz/ton 0.25 oz/ton 0.03 percent
46	Deerfly (probable extension of Glacier Peak prospect).	Disseminated silver--	174,000	Indicated and inferred; subeconomic.	Silver-------------- Gold---------------- Copper--------------	0.75 oz/ton 0.005 oz/ton 0.05 percent
			Railroad Creek mining district			
38	Ideal------------	Fissure vein---------	34,000	Indicated and inferred; marginal reserve.	Silver--------------	1.42 oz/ton
43	Crown Point mine	Shear zones----------	1,300	Measured and indicated; subeconomic.	Gold---------------- Silver-------------- Copper-------------- Lead---------------- Zinc---------------- Molybdenum disulfide	trace 2.92 oz/ton 2.6 percent 0.39 percent 0.72 percent 0.06 percent
23	Holden mine (adjoins Wilderness).	A. Shear zones (underground).	3 million	Measured; indicated and inferred; marginal reserve.	Copper-------------- Gold---------------- Silver-------------- Zinc----------------	1.1 percent 0.06 oz/ton 0.2 oz/ton 0.3 percent
		B. Tailings pile-----	9 million	Measured; marginal reserve.	Gold---------------- Silver-------------- Copper-------------- Zinc---------------- Pyrite (recoverable) Silica (free SiO_2)	0.048 oz/ton 0.1 oz/ton 0.07 percent 0.3 percent 5.0 percent unavailable
			Cascade mining district			
7	Pioneer (area 06031G).	Fissure vein (1.5 ft wide).	734,000	Indicated and inferred; restricted reserve.	Silver-------------- Lead---------------- Zinc---------------- Copper-------------- Gold----------------	6.46 oz/ton 6.4 percent 6.5 percent 0.52 percent 0.015 oz/ton
5	Silver Queen (adjoins Wilderness).	Sulfide (limestone-replacement forming two pod-shaped ore bodies).	60 (first pod)	Occurrence----------	Silver-------------- Lead---------------- Zinc---------------- Copper-------------- Gold---------------- Cadmium-------------	5.35 oz/ton 5.0 percent 2.0 percent 0.40 percent 0.01 oz/ton 0.01 percent
			9 (second pod)	----do--------------	Zinc---------------- Cadmium------------- Silver-------------- Copper-------------- Lead----------------	12.0 percent 0.18 percent 0.95 oz/ton 0.17 percent 0.65 percent
			Chiwawa mining district			
64	Royal Development mine (area 06031D).	Breccia pipe---------	8.5 million	Inferred; marginal reserve.	Copper-------------- Silver-------------- Tungsten------------	0.4 percent 0.9 oz/ton unavailable

[1]Numbers correspond to locations shown on accompanying map, MF-1652-A.
[2]U.S. Bureau of Mines and U.S. Geological Survey (1980).

Table 2.--Mines and prospects with possible undiscovered metallic resources in the Glacier Peak Wilderness and adjacent areas, Chelan, Skagit, and Snohomish Counties, Washington

[Properties are not sufficiently exposed or studied to enable estimate of tonnage and grade]

No. on map[1]	Property	Type	Commodities	Description and remarks	Sampling (sample lengths are in parentheses)
				Stehekin mining district	
35	Carmen------	Sulfide (limestone-replacement).	Lead Zinc Silver Copper Cadmium byproduct	On mineral belt extending to Holden mine. May intersect Copper King structure. Several shallow prospect pits.	Nineteen samples: ten ranged from 0.74 to 6.9 percent lead (5.0 and 4.0 ft, respectively) and averaged 2.0 percent; twelve ranged from 0.81 to 7.0 percent zinc (4.0 and 2.0 ft, respectively) and averaged 3.0 percent; nine ranged from 0.9 to 3.7 oz silver per ton (2.0 and 15.0 ft, respectively) and averaged 2.1 oz; six ranged from 0.10 to 0.53 percent copper (2.0 ft) and averaged 0.29 percent.
36	Copper King	Shear zone-----	Copper Cobalt Silver byproduct	Two adits, 5 ft and 14 ft long. Possible ore shoot may occur at intersection of this zone with trend of Carmen deposit. Cobalt may be only localized.	Seven samples: one assayed 0.34 percent cobalt, 0.11 percent copper, and 0.5 oz silver per ton (1.2 ft); one assayed 0.36 percent copper and 0.3 oz silver per ton (0.8 ft); one grab sample assayed 0.26 percent cobalt.
32	Goericke----	Porphyry copper	Copper Silver	Rugged terrain inhibits prospecting; on Holden trend.	Fifteen samples: one sample of float assayed 4.4 percent copper and 1.0 oz silver per ton; another sample of float assayed 0.9 percent copper; one chip sample assayed 1.2 oz silver per ton (2.0 ft); twelve samples of accessible parts of numerous pyritized areas on ridge crests were essentially barren.
				Railroad Creek mining district	
29	Mary Green--	Shear zones----	Copper Silver byproduct	Copper-rich pockets. Potential for limestone replacement; on Holden trend. Three adits as much as 370 ft long and several prospect pits.	Twenty-five samples: two of nine samples at workings near the ridge crest contained 1.5 percent copper (3.0 and 3.2 ft), another contained 0.14 percent copper (4.0 ft), and all ranged from 0.1 to 0.5 oz silver per ton. Sixteen samples from across isolated patches of pyritized rock along the canyon slope indicated no other anomalous mineral concentrations.
44	Victor------	Fissure vein---	Silver Lead Zinc	Sulfide veinlets. Possible extension of Crown Point mine. A 92-ft adit.	Five samples: one assayed 1.5 oz silver per ton, 1.4 percent lead, 4.0 percent zinc, 0.04 percent cadmium and 0.25 percent copper (0.2 ft); another assayed 1.4 oz silver per ton, 1.9 percent lead, and 0.60 percent zinc (0.2 ft).
24	Sevenmile-Antimony (adjoins wilderness).	Vein-----------	Antimony Gold byproduct Silver byproduct	Exploration target only. Also examined by U.S. Bureau of Mines in 1953. Caved adit 50 ft long.	Seven samples: one of three samples from the 1953 examination contained 2.72 percent antimony, and one sample assayed 1.0 percent nickel (no widths given); two of four samples from the 1977 examination assayed 0.48 and 0.31 percent antimony (select and grab samples, respectively); gold assayed from a trace to 0.01 oz per ton, and silver assayed from 0.2 to 0.4 oz per ton in those four samples.

			Chiwawa mining district		
53	Copper Point	Shear zones and possible breccia pipe.	Gold Silver Copper Lead Zinc	Patented claims. About 14 short adits and numerous prospect pits. Shear zones are very narrow. Contact of Entiat fault and Cloudy Pass pluton.	Eighty samples: fifteen assayed significant silver, ranging from 0.4 oz per ton (0.5 ft) to 5.1 oz per ton (0.6 ft) in chip samples, and 8.8 oz per ton in a select sample; ten chip samples assayed from 0.10 to 0.47 percent copper (0.6 to 1.0 ft, respectively), and eight select or grab samples assayed from 0.15 to 5.3 percent copper; six samples contained greater than 0.75 percent lead, ranging from 0.76 to 3.9 percent (0.5 and 0.6 ft, respectively); five contained greater than 0.75 percent zinc, ranging from 0.83 to 2.0 percent (0.6 and 0.3 ft, respectively); eighteen samples contained measurable gold, assaying from 0.01 to 0.05 oz per ton (1.0 ft).
56	Esmeralda---	Porphyry copper or breccia pipe.	Copper Gold Silver	Widespread hydrothermal-alteration area containing disseminated sulfides, and locally containing high grade gold and silver deposits at possible ancient fumaroles or boiling centers. Workings consist of five adits, two shafts, and at least six prospect pits.	Forty-two samples: nine assayed 0.1 percent or more of copper, ranging from 0.16 to 2.2 percent (2.0 and 1.2 ft, respectively); fifteen samples contained measurable gold--seven chip samples assayed from 0.01 to 0.15 oz per ton (1.1 and 1.2 ft, respectively), three select samples assayed 0.04 oz, 0.14 oz, and 0.37 oz per ton, and five grab samples assayed from 0.01 to 0.04 oz per ton; nine samples had assays ranging from 0.5 to 4.8 oz silver per ton (1.0 and 1.2 ft, respectively); six samples had an arsenic content greater than 1.0 percent, assaying as high as 29.0 percent in a select sample and 24.0 percent in a chip sample (1.2 ft).
57	Peacock-----	Epithermal deposit.	Silver Gold Copper Arsenic	Small deposits. Possible extensions of Esmeralda deposit. Several prospect pits.	Four samples: one select sample assayed 5.3 oz silver per ton, 0.07 oz gold per ton, 0.51 percent copper, and 27.0 percent arsenic; another sample assayed 1.4 oz silver per ton.
			Sampson mining district		
51	Fortress Mountain.	Porphyry copper	Copper	May be extension of Glacier Peak prospect.	Five grab samples of talus: one assayed 0.15 percent copper. Of more than 150 company surface samples, 25 assayed greater than 0.2 percent copper. Several shallow drill holes; the best averages 0.34 percent copper (87 ft).
			Unrecognized mining districts		
21	Cougar-Mountain Lion.	Disseminated---	Gold Copper Zinc	Pyritized rhyodacite plug at least 750 ft in diameter. Probably extends into wilderness, 1,000 ft to the west. Two adits 30 and 41 ft long.	Eight samples: four chip samples assayed from 0.01 to 0.03 oz gold per ton; (0.1 and 3.3 ft); one assayed 0.14 percent copper (3.3 ft); a select sample assayed 0.17 percent zinc.
92	Goff (area 06031A).	Unknown--------	Copper Silver Gold	Altered area of several square miles, containing small, localized, sulfide-bearing shear zones. Four adits: 105 ft, 80 ft, 10 ft, and 5 ft long; a 62-ft trench; at least four prospect pits.	Twenty-nine samples: four samples at the 5-ft adit assayed as much as 2.5 oz silver per ton, 0.01 oz gold per ton, and 0.05 percent copper in veinlets as much as 0.3 ft wide. Company reported 2 ft assaying 13.85 oz silver per ton, and 8.3 percent copper. Their location is vague.
2	Mount Buckindy.	Porphyry copper	Copper Molybdenum Silver byproduct	Remote, glacier-covered area. Company drilled five holes.	The best hole averaged 0.337 percent copper and 0.13 percent MoS_2 over 425 ft. Two intervals, 9 and 10 ft long, assayed more than 1 percent copper.

[1]Numbers correspond to locations shown on accompanying map, MF-1652-A.

that of our colleagues. The following summary is based on the recognition of specific geologic, geochemical, geophysical, and mines and prospects criteria characteristic of a distinct deposit type (Erickson, 1982; Cox, 1983). In evaluating areas of mineral potential, we have developed recognition criteria as defined by a mineral-deposit model, formulated those criteria in definable terms, and summarized our observations for mineralized areas in the study area. This approach is model dependent; should new mineral deposit models become more appropriate based on future study, the Glacier Peak folio (MF-1652) should provide the basic observational data for new resource assessments.

The models for deposit types used in this evaluation are presented in tables 3-6 using the following general recognition criteria:

1. Regional geologic setting and structure.
2. Local geologic environment, including rock type, structural relationships, alteration, and observed mineralized rock.
3. Geochemistry of rocks, stream sediments, heavy-mineral concentrates panned from stream sediments, and mineralogy of the heavy-mineral concentrates.
4. Geophysical expressions indicated by the aeromagnetic and gravity surveys.
5. Evidence of mining activity, known deposits, and exploration and claim activity.

Detailed descriptions of the specific recognition criteria used for each model type are given below, along with specific references to geologic descriptions or summaries of features of that deposit type.

The principal types of mineral deposits that occur, or may be expected to occur, in the study area are (A) hot-springs deposits (Au and Ag); (B) base- and precious-metal hydrothermal-vein deposits and limestone-replacement deposits associated with igneous intrusive rocks (Au, Ag, Pb, Zn, Cu, and As); (C) disseminated porphyry deposits of both the copper-rich and molybdenum-rich type (Cu, Mo, W, and Au); (D) volcanogenic massive-sulfide deposits in the metamorphic Holden schist and gneiss belt (Cu, Zn, Au, and Ag); (E) gold-bearing quartz veins resulting from regional metamorphism; (F) zoned ultramafic rocks containing pod-shaped deposits of chromium and platinum-group metals, or ultramafic rocks containing magmatic concentrations of nickel, cobalt, chromium, and platinum-group metals; and (G) placer-gold deposits. Each of these deposit types is briefly discussed below, and the field observations, interpretation of the geologic setting, geochemistry, mineralogy, gravity, magnetics, and mining activity data leading to the resource assessment are summarized in the accompanying tables (3-6).

A. Hot-springs deposits

Hot-springs deposits, noted primarily for their large-volume, low-grade gold potential (Radtke and others, 1980; Silberman, 1982) occur in young, uneroded belts of volcanic rocks that are dominantly dacite and andesite, with lesser amounts of rhyodacite and rhyolite. Shallow felsic intrusions appear to provide the heat, and the vent areas are characterized by extensive hydrothermal alteration, particularly silicification, and brecciation. Deposits are generally associated with caldera margins, normal faulting, or complex volcanic centers characterized by presence of small intrusive plugs. Disseminated pyrite is common. Altered rocks and stream sediments have moderate to high levels of arsenic, antimony, mercury, gold, and silver. Barite is common in the heavy-mineral concentrates. The type area for these deposit is in the Great Basin. Similar deposits have recently been found in the Eocene Chumstick formation along the extension of the Entiat fault south of the study area, near Wenatchee, Wash.

Five areas (A-1 to A-5, fig. 3) may possibly have hot-springs-type deposits: Gamma Ridge-Gamma Hot Springs, Goff (06031A), the Round Lake volcanics area (06031G), Kennedy Hot Springs, and Sulphur Hot Springs. The data for each area are summarized in table 3. Four of the five areas considered do not sufficiently satisfy the deposit criteria to consider them as having a moderate potential for the occurrence of precious-metal resources. Although the Goff prospect (A-1) has anomalous concentrations of the precious metals, it lacks many of the essential features of the hot-springs-deposit model, including evidence of extensive silicification or the presence of a venting hydrothermal system. Likewise, the Round Lake volcanics area (A-2) lacks many essential features. Both areas are classified as having a low potential for the occurrence of precious-metal resources in this type of deposit. Two of the three active hot-springs areas, Kennedy (A-4) and Sulphur Hot Springs (A-5), also lack essential features of the model, primarily the close spatial association with contemporaneous volcanic-vent areas. These two areas also have a low potential for the occurrence of precious-metal resources in a hot-springs deposit. The Gamma Ridge-Gamma Hot Springs area (A-3) probably represents a hot-springs system related to recent volcanic activity at Glacier Peak that vented through the older volcanic rocks (Tabor and Crowder, 1969, p. 22-23). The presence of silicified rock, large altered areas, and favorable geochemical anomalies suggests that area A-3 has a moderate potential for the occurrence of precious-metal resources in a low-grade, disseminated hot-springs deposit.

B. Hydrothermal-vein and limestone-replacement deposits associated with igneous rocks

Base- and precious-metal hydrothermal veins are common peripheral features associated with porphyry-type deposits. They occur in thick volcanic piles of andesitic to rhyolitic composition associated with tensional or extensional regional tectonic stress patterns. They generally form within several thousand feet of the surface and are spatially associated with centers of volcanic activity. Geochemical anomalies commonly observed in stream sediments may include arsenic, antimony, silver, gold, tellurium, lead, zinc, and copper. Heavy-mineral concentrates may contain arsenopyrite, chalcopyrite, pyrite, galena, sphalerite, scheelite, cinnabar, native gold, and various sulfosalt minerals, such as tetrahedrite and tennantite. Widespread evidence of sericitic, kaolinitic, carbonatic, and propylitic alteration may be present. Thin envelopes of potassic alteration in wall rock may also occur along veins where chalcopyrite is

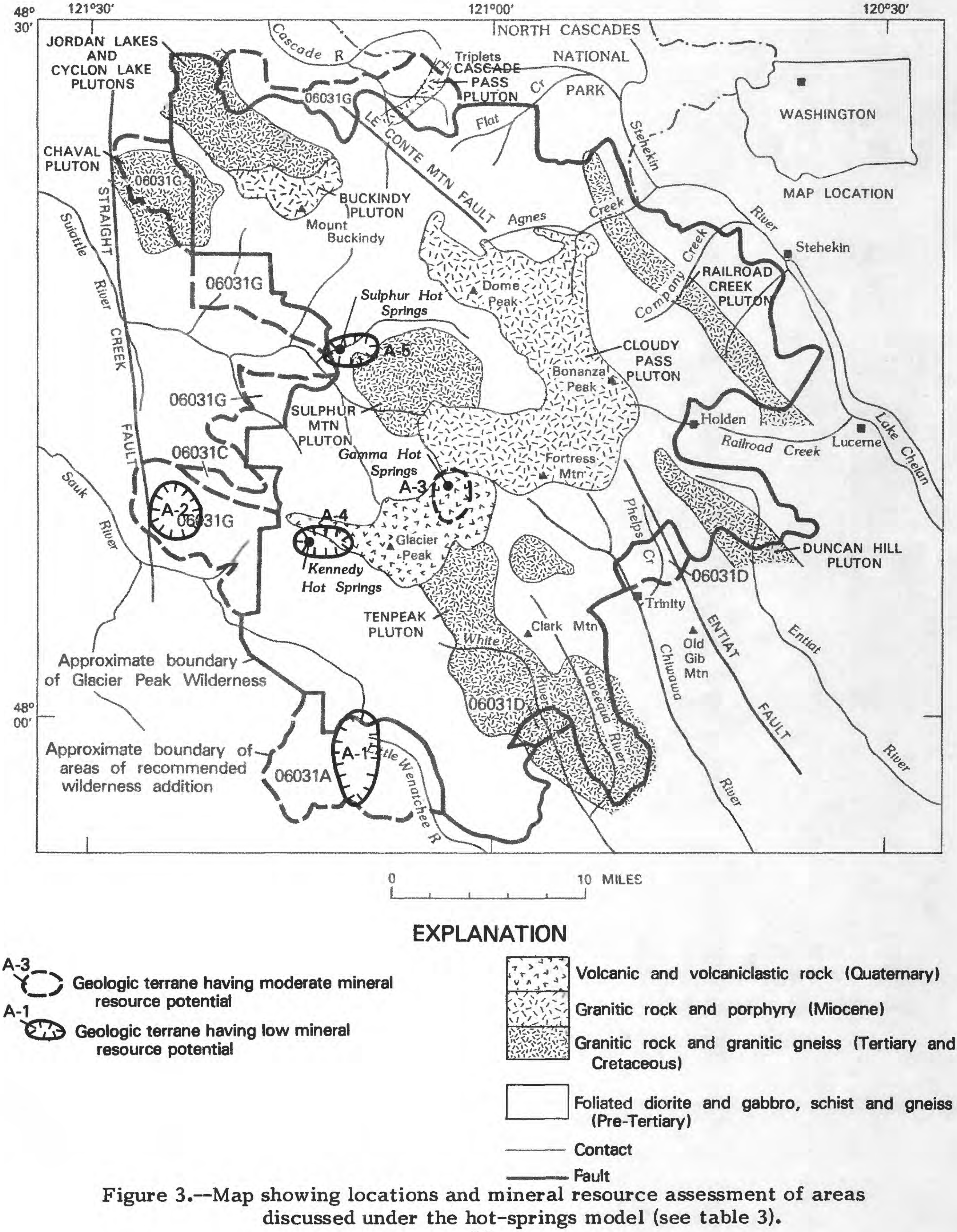


Figure 3.--Map showing locations and mineral resource assessment of areas discussed under the hot-springs model (see table 3).

Table 3.--Summary of data for the hot-springs-deposit model

[Field observations: +, feature observed; -, feature not present; ?, field observations not made or inconclusive. Geophysical anomalies: H, high; L, low; ?, no indication. Potential for occurrence of mineral resources: L, low; M, moderate. Minerals: Py, pyrite; Sch, scheelite; Ti-m, titanium minerals; Bar, barite. NA, not available]

Recognition criteria	Goff Prospect (area A-1)	Round Lake volcanics rocks (area A-2)	Gamma Ridge-Gamma Hot Springs (area A-3)	Kennedy Hot Springs (area A-4)	Sulphur Hot Springs (area A-5)
1. Regional geologic setting					
A. Intermediate to felsic volcanic rocks	+	+	+	+	-
B. Presence of caldera or volcanic center containing intrusive phases	+	+	+	?	-
C. Presence of high-angle normal faulting	?	?	?	?	?
2. Geologic environment					
A. Dacitic to rhyolitic volcanics and volcaniclastic rocks	+	+	+	-	-
B. Shallow level of erosion	+	+	+	-	-
C. Local structural fracturing	+	-	?	?	?
D. Primary porosity/permeability in rocks	+	+	+	-	-
E. Hydrothermal fracturing/brecciation	?	-	?	?	?
F. Alteration	Limonite	Limonite	Propylitic argillic	?	?
G. Silicification	-	-	+	-	-
H. Stockworks/veinlets	-	-	-	-	-
I. Presence of active hot springs	-	-	+	+	+
J. Presence of travertine	-	-	+	+	+
3. Geochemistry					
A. Anomalous anions or cations in hot-springs waters	NA[1]	NA[1]	NA[1]	[1]Cu, Zn, Mo	NA[1]
	NA[2]	NA[2]	[2]HCO_3^-, Cl^-	[2]Cl^-	[2]HCO_3^-, $SO_4^=$, Cl^-
	NA[3]	NA[3]	[3]H_2S, Cl^-	[3]HCO_3^-, Cl^-, Zn, Hg	[3]H_2S

B. Anomalous elements in stream sediments	Mo, Cu, Pb, Co, Mn, Zn, Ag, Au	Au, Pb	Au, Ag	None	Mo, Ni
C. Anomalous acid-soluble elements in stream sediments	As, Cu, Pb, Zn, Ag, P, Co, Ni, Mn, Ba	Cu, Co, Ni, Mn, Ba, W, Zn, As, Ti, Nb	Mo, Mn, Ni, Co, W, As, Sr, Ti, Nb	None	Cu, Zn, Co, Ni, Mn, Ba, Sr, Cr
D. Anomalous elements in panned concentrates	Mo, Cu, Pb, Hg, Ag, Co, W, Sn, Bi, Ba, B	Cu, Pb, Hg, Ag, As, Co, Ba, B, Bi, W	Cu, Pb, Hg, As, Ag, Co, Ba	Mn, Cu, Co	Mn, Co, Ba
E. Mineralogy of heavy-mineral concentrates	Py, Sch	Py, Ti-m	Py, Bar	NA	NA
F. Anomalous halo elements in rocks	Ba, Ni(?)	Ba	Mn, Ba	-	-
G. Anomalous commodity elements in rocks	Ag, Cu, Mo, Pb, Sn, Zn	Cu, Ag	Mo, Ag	-	-
4. Geophysics					
A. Magnetic indication	H	H	?	H	?
B. Gravity indication	?	?	L	?	?
5. Mining activity summary					
A. Known deposits	None	None	None	None	None
B. Mineral occurrences or zones containing possible undiscovered resources	Goff([4]#92, [5]G-33), Cu, Ag, Au	None	None	None	None
C. Number of prospects, workings, and the like (not including 5A)	9	0	0	0	0
6. Resource assessment	L	L	M	L	L

[1]Data this study.

[2]Data from Tabor and Crowder (1969).

[3]Mariner and others (1982).

[4]Stotelmeyer and others (in press).

[5]Grant (1982).

abundant. Brecciation is a common feature. Ore minerals may be either disseminated or vein deposits in vugs, fractures, and open spaces (Barton, 1982; Berger, 1982; Berger and Eimon, 1983). The ores of the Monte Cristo district southwest of the study area are an excellent example of this type of hydrothermal vein deposit (Spurr, 1901; Church and others, 1983c).

High-grade, localized deposits may also result when hydrothermal solutions react with limestone or marble to form replacement deposits. Although no mappable limestone units (1:100,000 scale) are present in the study area, local geology also makes this type of deposit a feasible variant of the hydrothermal-vein deposit model; the Carmen property (table 2, no. 35) is a possible example of a hydrothermal limestone-replacement deposit. The data for areas having potential for base- and precious-metal vein deposits are summarized in table 4; areas are shown in figure 4 (areas B-1 to B-8).

Area B-1 has a high potential for the occurrence of precious-metal resources and contains three deposits having identified resources. The Deerfly prospect, a disseminated-silver deposit probably associated with the Glacier Peak hydrothermal system, has demonstrated resources of 174,000 tons containing 0.75 oz silver/ton, with some gold and copper. The deposit is in pervasively sheared granodiorite containing closely spaced quartz veins and showing sericitic alteration. Pyrite, arsenopyrite, chalcopyrite, pyrrhotite, and tourmaline are abundant; the rock also contains minor galena and sphalerite. The Crown Point mine has demonstrated resources of 1,300 tons containing 2.9 oz silver/ton, 2.6 percent copper, 0.39 percent lead, and 0.72 percent zinc. This deposit is in shears and small veins in a large quartz pod in weakly altered granodiorite of the Cloudy Pass pluton. The mine produced 10-12 tons of molybdenum ore (1901-02), and some museum specimens of molybdenite were removed, but the deposit is small. The Victor prospect, 1,800 ft north of the Crown Point mine, is probably part of the same hydrothermal system. Stringers of sulfides occur in altered granodiorite; galena, sphalerite, chalcopyrite, and bornite were identified, and ruby silver may be present. The Ideal prospect has demonstrated resources of 34,000 tons containing 1.42 oz silver/ton. It is on a quartz vein in orthogneiss cut by numerous lamprophyre dikes containing pyrite. Geologic inference suggests that the area of the Ideal prospect is underlain by the Cloudy Pass batholith.

Area B-2, which includes the Esmeralda and Peacock claims along Phelps Ridge, has a high potential for the occurrence of base- and precious-metal resources. The presence of scorodite (a hydrous iron arsenate) and abundant amorphous silica suggests shallow deposition of ore. Area B-2, Red Mountain, consists of extensively pyritized and altered gneiss overlying the Cloudy Pass pluton (Grant, 1982). It has a pronounced red color anomaly and widespread geochemical anomalies.

Area B-3, north of area B-1, in the Stehekin mining district, has a high potential for the occurrence of base- and precious-metal resources in hydrothermal veins and in limestone-replacement deposits in pre-Tertiary gneisses. Widespread geochemical anomalies reflect the distribution of sulfides along tensional shears in the roof rocks over the Cloudy Pass pluton or along nearby structural features. The Carmen deposit, which is either a tactite or limestone-replacement deposit, and the Copper King properties are along the same structure and have possible undiscovered base- and precious-metal resources. The Goericke property on Company Creek has possible undiscovered resources.

Area B-4 has a high potential for the occurrence of base- and precious-metal resources. A major sulfide vein at the Pioneer patented claims is in area 06031G. Demonstrated and inferred resources are 734,000 tons of silver-lead-zinc ore containing 6.46 oz silver/ton, 6.4 percent lead, 6.5 percent zinc, 0.52 percent copper, and 0.015 oz gold/ton. The deposit is adjacent to a large breccia pipe at the Triplets (Tabor, 1963). The Silver Queen prospect, just outside the boundary of the recommended wilderness addition, is a limestone-replacement deposit in Cascade River Schist of Misch (1966). It has an estimated 69 tons of mineralized rock in high-grade pods, containing 4.8 oz silver/ton, 5.0 percent lead, 2.0 percent zinc, and some copper, gold, and cadmium (see table 1). An adjacent area, B-5, has similar geochemical, geophysical, and geologic features (table 4) and has a moderate potential for the occurrence of base- and precious-metal resources in hydrothermal veins.

Area B-6 is on the Glacier Peak transverse shear belt of Grant (1969) near a granitic plug. This system has produced an intense red color anomaly, reflecting the surrounding pyritic shell, and is characterized by isolated geochemical anomalies and a favorable magnetic signature. No exploration work has been done in the area. On the basis of this study, area B-6 is assigned a low potential for the occurrence of base-metal resources in hydrothermal veins.

Area B-7, located mainly in area 06031A, south of the wilderness, is defined largely by geochemical anomalies associated with volcanic plugs. Company assay records from an adit in area B-7 indicate a silver vein having 13.85 oz silver/ton and 8.3 percent copper (Stotelmeyer and others, 1982), but there are no indications that this is anything other than a localized high-grade occurrence. Based on this study, area B-7 is also assigned a low potential for the occurrence of precious-metal resources.

The Cougar-Mountain Lion prospect (B-8), southeast of, but immediately adjacent to, the study area, is associated with a rhyodacite plug containing disseminated sulfides and is classified as having a low potential for the occurrence of base- and precious-metal resources in hydrothermal veins. Area B-8 extends into the wilderness.

C. Porphyry deposits

Porphyry deposits, that is, disseminated deposits formed by convecting hydrothermal systems in the rocks surrounding an intrusive, are generally classified according to the geologic conditions of emplacement. Both the volcanic- and plutonic-type porphyry deposits are common in the Canadian cordillera (Brown, ed., 1976). Hollister (1979) has briefly summarized the distribution of known porphyry-type deposits from the Canadian cordillera south into the Cascade Range of Washington and Oregon. Both copper- and molybdenum-rich systems occur in the study area.

Porphyry deposits are associated with calc-alkaline igneous intrusive belts that passively intrude regional zones of structural weakness caused

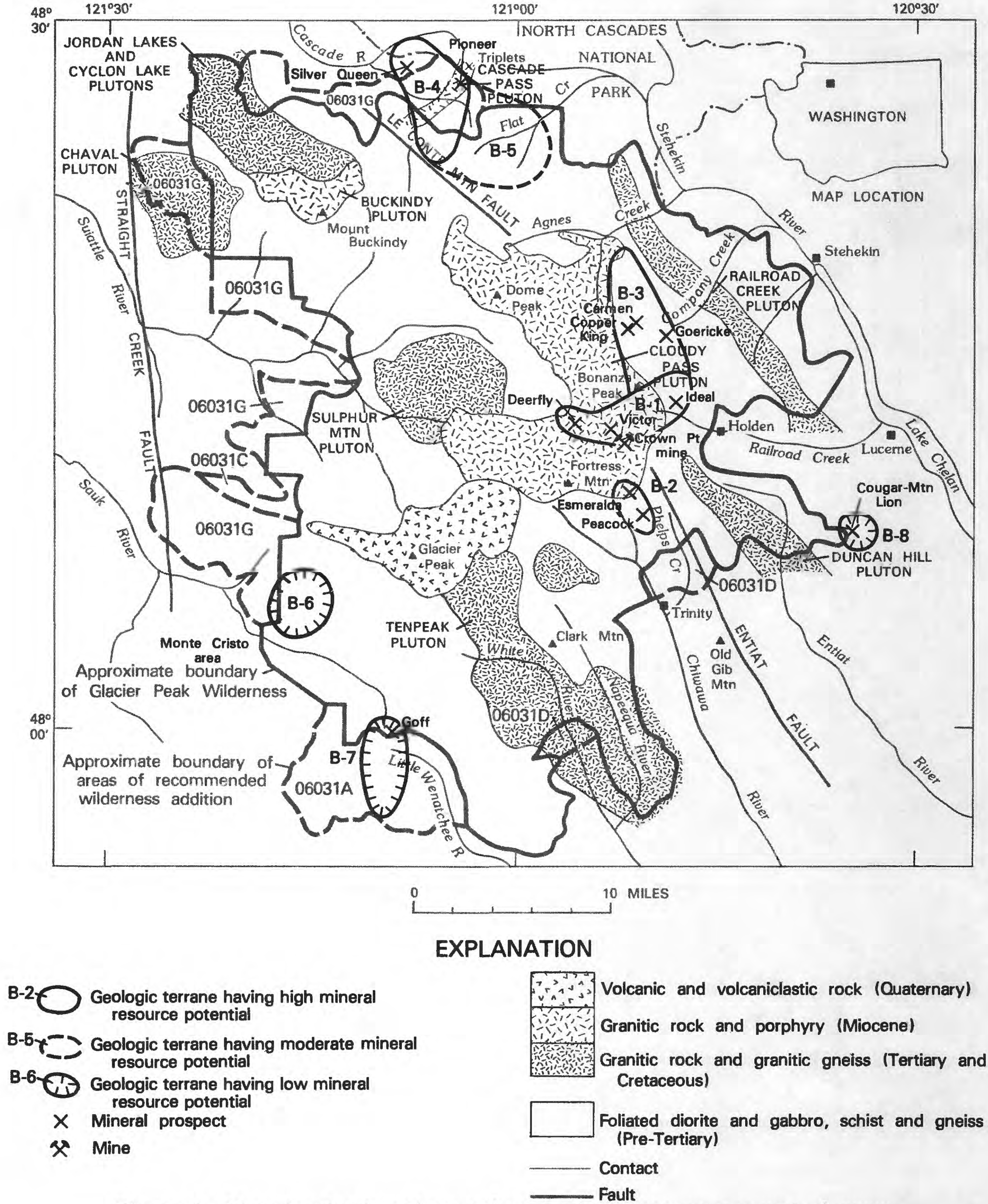


Figure 4.--Map showing locations and mineral resource assessment of areas discussed under the base- and precious-metal-vein model (see table 4).

Table 4.--Summary of data for base- and precious-metal hydrothermal-vein-deposit model

[Field observations: +, feature observed; -, feature not present; ?, field observations not made or inconclusive. Geophysical anomalies: H, high; L, low; RLG, regional linear gradient; ?, no indication. Potential for occurrence of mineral resources: L, low; M, moderate; H, high. Minerals: Sch, scheelite; Tour, tourmaline; Py, pyrite; Ti-m, titanium minerals; Cpy, chalcopyrite; Bar, barite; Gal, galena]

Recognition criteria	Area B-1	Area B-2	Area B-3	Area B-4	Area B-5	Area B-6	Area B-7	Area B-8
1. Regional geologic setting								
A. Calc-alkaline igneous belt	+	+	+	+	-	+	+	+
2. Geologic environment								
A. Dacitic/calc-alkaline volcanics	-	+	+	-	-	+	+	+
B. Associated with intrusive center	+	+	+	+	-	+	+	+
C. Presence of dike swarms	+	+	?	+	+	?	+	-
D. Shallow-level intrusion	+	+	+	+	?	+	+	+
E. Tensional fracturing	+	+	+	+	+	+	+	-
F. Primary porosity/permeability	-	-	-	-	-	-	+	-
G. Presence of intrusive breccia (breccia pipe or explosion breccia)	-	+	+	+	+	-	-	+
H. Alteration	Phyllic, sericitic	Phyllic, sericitic	Limonite	Quartz veining	Pyrite/ limonite	Propylitic	Limonite	Pyrite/ limonite
I. Disseminated pyrite	+	+	+	-	+	+	+	+
J. Vein filling	+	+	+	+	+	?	+	?
3. Geochemistry								
A. Anomalous elements in stream sediments	Mo, Pb, Zn, Ag, Au, Co, Mn, Ni	Mo, Cu, Pb, Ag, As, Co, Au, Sb	Mo, Zn, Au, Co	Mo, Cu, Pb, Zn, Ag, Au	Cu, Zn, Au, Ag, Co, Mn	Au, Cu, Pb, Mo	Mo, Cu, Pb, Co, Mn, Ag, Au, Zn	Pb, Zn, Ag, Au, Mn, Mo
B. Anomalous acid-soluble elements in stream sediments	Mo, Cu, Pb, Zn, Co, Mn, As, Ti	Mo, Cu, Pb, Zn, Co, Mn, As	Mo, Cu, Zn Co, Mn	Cr, Cu, Pb, Zn, Co, P, Sr, Ni, Mn, Ba	P, Mo, Cu, Zn, Co, Ba, Sr, Ni, Mn, Pb, As	Cu, Zn, Nb, Co, As, Ni, W, Ba, Mo, Mn	Cu, Pb, Zn, Ag, Co, Ni, Mn	Mo, Cu, Pb, Zn, Mn
C. Anomalous elements in panned concentrates	Mo, Cu, Pb, Ag, As, Co, Hg, W, Sn, Bi, B, Ba	Cu, Pb, Hg, Sn, Nb, Ba, B	Cu, Mo, Pb, Hg, Co, W, Bi, Ba, B	Cu, Pb, Hg, Ag, As, Co, W, Ba, B, Sn, Bi	Cu, Pb, Hg, Ag, As, Co, Ba, B, W, Sn	Cu, Pb, Hg, Ag, As, W, Nb, B	Mo, Cu, Pb, Hg, Ag, Co, W, Sn, Bi, Ba, B	Cu, Pb, Hg, Ag, Co, Mo, Bi, Sn
D. Mineralogy of heavy-mineral concentrates	Sch, Tour, Py, Ti-m	Sch, Py, Ti-m	Cpy, Py, Bar, Sch, Ti-m, Tour	Py, Gal, Sch, Ti-m	Py, Sch, Bar, Ti-m	Py, Ti-m	Py, Sch	Py, Ti-m
E. Anomalous halo elements in rocks	Mn, B, Ba, Bi, Cd, Zn, Sb	B, Mn, As, Sb, Bi, Ba	Mn, Sb	Ba, As, Sb, Mn, Cd	Mn, B, Ni, As, Sb	None	Ba, Ni(?)	None
F. Anomalous commodity elements in rocks	Ag, Pb, As, Mo	Ag, Au, Pb, Zn, Cu, Mo, W	As, Ag, Au, Cu, Pb, W, Zn	Pb, Zn, Ag, Cu, Mo	Ag, Pb, Cu, Mo, Zn	Ag, As	Ag, Cu, Mo, Pb, Sn, Zn	None

4. Geophysics								
A. Magnetic indication	L	?	RLG	H	H	L	H	H
B. Gravity indication	L •	?	?	L	?	L	?	?
5. Mining activity								
A. Known deposits	Ideal ([1]#38), Ag Deerfly ([1]#46, [2]G-15), Ag Crown Pt. mine ([1]#43, [2]G-6), Au, Ag, Cu, Mo	None	None	Pioneer ([1]#7, [2]G-32), Pb, Ag, Zn, Cu, Au Silver Queen ([1]#5), Pb, Ag, Zn, Cu, Au, Cd	None	None	None	None
B. Mineral occurrences or zones with possible undiscovered resources	Victor ([1]#44, [2]G-29), Ag, Pb, Zn	Peacock ([1]#57), Au, Ag, Cu, As Esmeralda ([1]#56, [2]G-5), Au, Ag, Cu, As	Goericke ([1]#32, G-11), Cu, Ag Carmen ([1]#35), tactite-Cu, Pb, Zn, Ag Copper King ([1]#36), Cu, Co, Ag	Cascade ([2]G-30), Pb, Ag Epoch ([2]G-31), Pb, Ag	None	None	Goff ([1]#92, [2]G-33), Cu, Ag, Au	Cougar ([1]#21), Au, Zn, Cu
C. Number of prospects, workings, and the like (not including 5A)	8	20	7	4	0	0	9	6
6. Resource assessment	H	H	H	H	M	L	L	L

[1]Stotelmeyer and others (in press).

[2]Grant (1982).

by crustal extension or strike-slip faulting. The igneous rocks of the volcanic-porphyry deposits have generally intruded slightly older volcanic rocks whereas the plutonic-porphyry deposits are found in complex batholithic terranes. Commonly, porphyry deposits are associated with breccia pipes and (or) dike swarms. Evidence of hydrothermal alteration is widespread. The porphyry deposits may be associated with a local gravity high.

The volcanic-porphyry deposit is generally characterized by argillic, phyllic, and propylitic alteration halos; the potassic alteration is rarely exposed. Alteration of mafic minerals to magnetite may produce a magnetic high associated with the deposit. Base- and precious-metal hydrothermal-vein deposits are common peripheral associations. Stockwork may have developed in the volcanic edifice or autobrecciation may indicate a shallow igneous cupola. Good circulation in permeable rocks is needed to form a deposit. Geochemical anomalies commonly observed in stream sediments may include manganese, copper, molybdenum, lead, zinc, silver, and gold. Heavy-mineral concentrates may contain tourmaline, gold, barite, molybdenite, galena, chalcopyrite, pyrite, bornite, scheelite, and sphalerite. Geochemical anomalies from this medium may contain barium, tin, tungsten, bismuth, and mercury, in addition to those elements anomalous in stream sediments. (See Grant, 1969; Lowell and Guilbert, 1970; Brown, ed., 1976; Pilcher and McDougall, 1976; Colley and Greenbaum, 1980; Beane and Titley, 1981; Titley and Beane, 1981; Chaffee, 1982a, b; Cox, 1982; Moss, 1982; Cox, 1983).

The plutonic-porphyry deposits are characterized by propylitic and phyllic alteration peripheral to a weakly developed potassic alteration zone surrounding the central, copper-rich ore zone. Veins of quartz, sericite, and pyrite form an intensely developed stockwork; deposits formed in rock fractured solely by regional tectonic stresses are generally low grade. Geochemical halos of base and precious metals are common, and evidence of a contact-hornfels zone may be difficult to distinguish in a complex batholithic intrusion. Geochemical anomalies found in stream sediments may include manganese, copper, molybdenum, cobalt, lead, zinc, silver, gold, and boron. Heavy-mineral concentrates commonly contain chalcopyrite, pyrite, tourmaline, galena, sphalerite, scheelite, and gold. Geochemical anomalies from concentrates may include tungsten, tin, arsenic, and barium in addition to those elements anomalous in the stream sediments. Hydrothermal alteration may cause replacement of magnetite by pyrite, resulting in the association of a magnetic low with the deposit (see Grant, 1969; Brown, 1976; Brown, ed., 1976; Pilcher and McDougall, 1976; Chaffee, 1982a, b; Cox, 1982; Moss, 1982).

One of the more important questions in evaluating the plutonic-porphyry deposits is the depth of erosion. Durning and Davis (1978) examined the geological and geochemical expressions of the exposed root zones of porphyry deposits and concluded that important characteristics of root zones are general absence of porphyritic texture in the intrusion, absence of breccia pipes, lack of closely spaced fractures, absence of vugs in veinlets, and sparsity of dikes. Chalcopyrite, pyrite, and molybdenite are present, but the chalcopyrite content decreases with depth. Secondary magnetite commonly replaces mafic minerals and sulfides. Poorly developed lead, zinc, silver, and gold geochemical halos are evident. There is extensive metasomatic alteration adjacent to veinlets, and pod-like, pegmatitic masses of quartz and potassium feldspar accompany magnetite and sulfides, analogous to the barren quartz core found in the Glacier Peak deposit (Grant, 1969). Zoning patterns of alteration are not well defined.

The principal mineral resources of the study area are in porphyry-type deposits. The resources and reserves defined by subsurface drilling at the Glacier Peak deposit (see tables 1 and 5; fig. 5, area C-1) constitute the most important known deposit. The area around the Glacier Peak prospect has 1.9 billion tons of demonstrated resources containing 0.334 percent copper and 0.02 percent molybdenum; tungsten, gold, and some silver are probable coproducts. The area contains 17 patented claims. The deposit is a late intrusive phase of the Cloudy Pass pluton that has disseminations and veinlets of sulfide minerals. Many of the features described by Grant (1969) as important elements in the plutonic-porphyry deposit were intersected by Bear Creek Mining Co. drilling at the site of the main ore body. The precious-metal deposit at the Deerfly prospect (B-1, fig.4) and the geochemical anomalies in area C-2 constitute the precious-metal halo surrounding this porphyry deposit. The potassic, sericitic, and chloritic (propylitic) zones, as mapped by Bear Creek Mining Co., close within the boundaries of area C-1. The axis of the deposit trends east-west and is marked by a linear magnetic low within the Cloudy Pass magnetic anomaly (Flanigan and others, 1983). The Fortress Mountain, Copper Point, and Esmeralda properties also have possible undiscovered resources (see table 2). Area C-1 (table 5) has a high potential for the occurrence of base-metal resources of copper, molybdenum, tungsten, and gold, and possible lead, zinc, and silver byproducts in porphyry deposits.

Area C-2, immediately west of C-1, has base- and precious-metal geochemical anomalies, but erosion has cut deeply into the interior of the Cloudy Pass pluton, and no indications of mineralization were observed in the rocks. This area is analogous to the barren metal halos surrounding the root zones of porphyries as discussed above (Durning and Davis, 1978, p. 88) and has a low potential for the occurrence of base- and precious-metal resources in porphyry deposits.

Area C-3 marks the axis of intrusion of the Cloudy Pass pluton along the Entiat fault. At the south end of area C-3, in area 06031D, the Royal Development mine, a breccia pipe, has inferred resources of 8.5 million tons containing 0.4 percent copper and 0.9 oz silver/ton. Similar breccia pipes are present at the north end of area C-3 at the Esmeralda and Peacock prospects (C-1). Area C-3 has a high potential for the occurrence of base-metal resources in breccia pipes or disseminated porphyry deposits.

Area C-4 is largely unexplored, but contains three deposits discussed earlier as having possible undiscovered resources (see tables 2 and 5). Only the Goericke prospect has altered and mineralized rock typically associated with porphyry-copper deposits. Plugs and dikes of porphyritic quartz diorite and granodiorite intrude the schist and gneiss (Grant, 1982, p. 28). The regional linear gradient of the magnetic data suggests that the contact with the Cloudy Pass

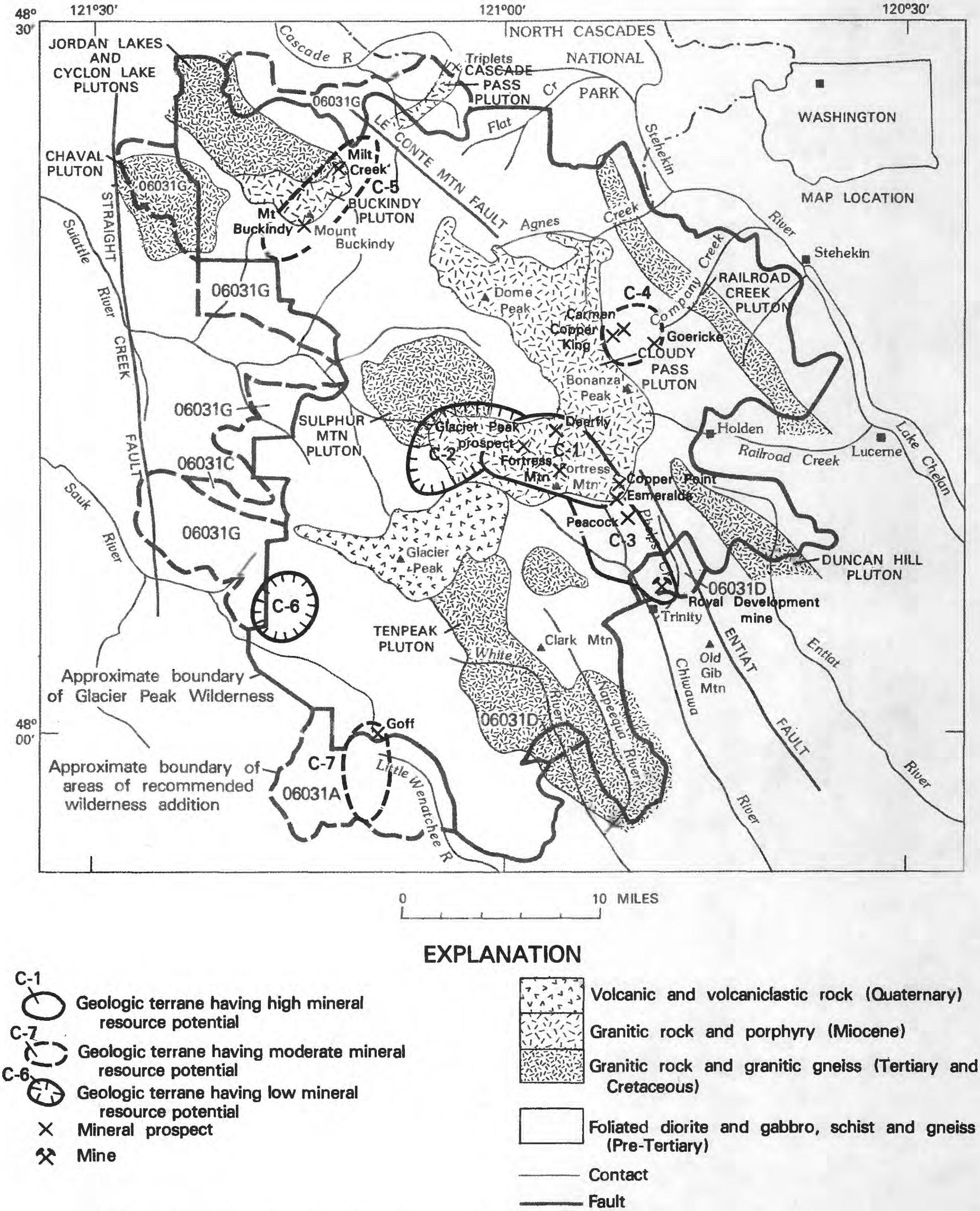


Figure 5.—Map showing locations and mineral resource assessment of areas discussed under the porphyry model (see table 5).

Table 5.--Summary of data for the porphyry copper-molybdenum-deposit model

[Field observations: +, feature observed; -, feature not present; ?, field observations not made or inconclusive. Geophysical anomalies: H, high; L, low; RLG, regional linear gradient; ?, no indication. Potential for occurrence of mineral resources: L, low; M, moderate; H, high. Minerals: Moly, molybdenum; Py, pyrite; Sch, scheelite; Bar, barite; Cpy, chalcopyrite; Ti-m, titanium minerals; Tour, tourmaline; Gal, galena. NA, not available]

	Plutonic porphyry type									Volcanic- porphyry type	
	Area C-1			Area C-2	Area C-3	Area C-4	Area C-5			Area C-6	Area C-7
Recognition criteria	Glacier Peak deposit	Fortress Mtn.	Esmeralda-Copper Pt.		Royal Development mine		Mount Buckindy	Milt Creek	Triplets	West Red Mtn.	Goff Prospect
1. Regional geologic setting											
A. Calc-alkaline igneous belt	+	+	+	+	+	+	+	+	+	+	+
B. Regional structural features	+	-	+	+	+	+	+	+	+	+	-
2. Geologic environment											
A. Quartz-diorite/granodiorite or intermediate volcanic rocks	+	+	+	+	+	+	+	+	+	+	+
B. Level of erosion	intermediate	intermediate	shallow	deep	shallow	shallow	intermediate	shallow	shallow	shallow	shallow
C. Age of igneous event	20 m.y.(?)	Miocene(?)	20 m.y.(?)	20 m.y.(?)	20 m.y.(?)	20 m.y.(?)	14 m.y.(?)	Miocene(?)	18 m.y.(?)	Miocene(?)	Miocene(?)
D. Porphyritic texture	+	-	+	?	+	+	+	+	+	-	-
E. Dike swarms	+	+	+	-	-	+	+	+	+	?	?
F. Igneous cupola	+	+	+	?	+	+	+	-	+	+	+
G. Tensional fracturing	+	+	+	-	+	+	-	+	+	+	+
H. Primary permeability/ porosity	-	-	-	-	-	-	-	-	-	-	?
I. Presence of an intrusive breccia (breccia pipe or explosion breccia)	-	-	+	-	+	+	+	+	+	-	-
J. Presence of stockwork	+	+	+	-	-	?	+	-	?	?	?
K. Alteration	Propylitic/ sericitic/ potassic	Propylitic/ sericitic/ potassic	Phyllic/ sericitic	none observed	Propylitic/ phyllic	Chlorite/ sericite	Phyllic/ sericitic	Propylitic/ phyllic/ sericitic	Limonite	Propylitic	Limonite
L. Pyrite envelope	+	+	+	-	-	?	-	+	-	+	+
M. Barren quartz core	+	?	?	?	?	?	?	?	?	?	?
3. Geochemistry											
A. Anomalous metals in stream sediments	Mo, Cu, Pb, Ag, Zn, Au	None	Mo, Cu, Ag, Au	Pb, Zn, Ag, Au	Cu, Co, Ag	Mo, Zn, Co, Au	Mo, Cu, Pb, Ag, Au, Co	Mo, Cu, Zn, Pb, Ag, Au	Mo, Cu, Pb, Zn, Ag, Au	Au, Cu, Pb, Mo	Mo, Cu, Pb, Zn, Ag, Au, Co, Mn
B. Anomalous acid-soluble metals in stream sediments	As, Mo, Cu, Zn, Ti, Pb, Mn, Ba, Nb	Mo, Cu, As	Mo, Cu, Pb, Co, As, Nb, Ti	Mo, Cu, Pb, Zn, Ag, As, Sr, Ti	Cu, Zn, As, Ti, Sr	Mo, Cu, Zn, Co, Mn	Mo, Cu, Zn, Co, Pb, As, Ti, Nb	As, Mo, Cu, Pb, Zn, Ba, Co, Ni, Mn, Sr, Cr	P, Mo, Cu, Pb, Zn, As, Ba, Ni, Co, Mn, Sr	Nb, Cu, Zn, Co, Ni, W, Mo, Mn, As, Ba	Cu, Pb, Zn, Ag, Co, Ni, Mn
C. Anomalous metals in panned concentrates	Mo, Cu, Pb, Ag, As, Co, W, Sn, Bi, Hg, B, Ba	Cu, As, Co, Mn, W, Sn, Bi, Ba, B	Cu, Pb, Ag, As, Co, Mo, B, W	Mo, Cu, Pb, Hg, As, Ag, Co, W, Sn, B, Nb, Ba, Bi	Co, Mn, Cu, Pb, Ag, W, Bi	Cu, Co, Mn, B	Mo, Cu, Pb, Hg, As, Co, Ag, W, Sn, Bi, Nb	Mo, Cu, Pb, Ag, As, Co, W, Sn, Bi, Nb, Ba, B	Mo, Cu, Pb, Ag, As, Hg, Co, W, Sn, Bi, Ba	Cu, Pb, Hg, Ag, As, W, Nb, B	Mo, Cu, Pb, Hg, Ag, Co, W, Sn, Bi, Ba, B
D. Mineralogy of heavy-mineral concentrates	Moly, Py, Sch, Bar, Cpy, Ti-m, Tour	Sch, Tour, Ti-m	Sch, Py, Ti-m	Py, Ti-m	NA	Cpy, Py, Bar, Sch, Ti-m	Moly, Py, Sch, Ti-m, Tour	Py, Sch, Ti-m	Moly, Cpy, Gal, Py, Sch, Ti-m	Py, Ti-m	Py, Sch

E. Anomalous halo elements in rocks	As, Ag, B, Ba, Pb, Sb, Mn, Zn	As, Mn, Ag, B	B, Mn, As, Sb, Bi, Ba	None	As, Ba, Bi, Cd, Pb, Sb, Zn	As, B, Ba, Sb, Zn	B, Mn, As, Bi, Zn	Mn, As, Ba, Pb	Mn, As, B, Ba, Bi, Sb	Ag, As	Ba, Pb, Zn, Ag
F. Anomalous commodity elements in rocks	Cu, Co, Bi, Au, Ag, Mo, Sn, W, Pb	Cu, Mo, Pb	Cu, Mo, Pb, Ag, Au, Zn, W	None	Ag, Au, Cu, Mo, Sn, W	Au, Cu, Pb, Zn	Cu, Mo, Pb, Sn	Ag, Cu, Mo, Zn	Ag, Co, Cu, Mo, Pb, Zn	None	Cu, Mo, Sn
4. Geophysics											
A. Magnetic indication	local L on H	H	H	local L on H	?	RLG	H	H	H	L	H
B. Gravity indication	L	L	L	L	?	H	?	L	L	L	?
5. Mining activity summary											
A. Known deposits and commodities	Glacier Peak ([1]#48, [2]G-1), Cu, Mo, Ag, Au, W------- Deerfly ([1]#46, [2]G-15), Ag, Au, Cu------------------ Crown Pt. mine ([1]#43, [2]G-6), Au, Ag, Cu, Pb, Zn, Mo			None	Royal Development mine ([1]#64), Cu, Ag, W	None	Pioneer ([1]#7, [2]G-32), Pb, Ag, Zn, Cu, Au-- Silver Queen ([1]#5), Pb, Ag, Zn, Cu, Au, Co		None	None	None
B. Mineral occurrences or zones containing possible widespread resources	Fortress Mtn. ([1]#51, [2]G-3), Cu--------------------- Victor ([1]#44, [2]G-29), Ag, Pb, Zn-------------------- Copper Pt. ([1]#53, [2]G-24), Au, Ag, Cu, Pb, Zn-------- Esmeralda ([1]#56, [2]G-5), Cu, Au, Ag, As--------------			None	Peacock ([1]#57), Ag, Au, Cu, As	Goericke([1]#32, [2]G-11), Cu, Ag Carmen ([1]#35), Pb, Zn, Ag, Cu, Cd Copper King ([1]#36), Cu, Co, Ag	Mount Buckindy ([1]#2, [2]G-2), Cu, Mo,Ag----- Cascade ([2]G-30), Pb, Ag------------------ Epoch ([2]G-31), Pb, Ag---------------------		None	None	Goff ([1]#92, [2]G-33), Cu, Ag, Au
C. Number of prospects, workings, and the like (not including 5A)	25	25	25	0	6	6	5	5	5	0	9
D. Drilling activity	At least 75 drill holes with more than 50,000 ft of core (Grant, 1982)	Three drill holes, 263 ft of core (Grant, 1982)	None	None	Many drill holes, more than 10,000 ft of core	None	Five drill holes, 2,280 ft of core (Grant, 1982)	None	None	None	None
E. Resource assessment	H	H	H	L	H	M	M	M	M	L	M

[1]Stotelmeyer and others (in press).
[2]Grant (1982).

pluton is nearby (Flanigan and others, 1983). This area has a moderate potential for the occurrence of base-metal resources in disseminated porphyry deposits.

Area C-5, in the vicinity of Mount Buckindy, has a moderate potential for the occurrence of copper and molybdenum resources in porphyry deposits. Widespread geochemical anomalies and locally altered rock are present; two breccia pipes are exposed on Mount Buckindy. The best intercepts from five drill holes in an area near the summit of Mount Buckindy averaged 0.34 percent copper and 0.13 percent molybdenum. Widespread geochemical anomalies along strike to the northeast in Milt Creek are described by Grant (1982, p. 24-25) as fracture-controlled mineralization. Propylitic alteration is widespread, numerous porphyritic dikes containing sulfides occur throughout the area outlined, as well as to the south of it, and vugs of quartz crystals occur in hydrothermal veins in the schist. This area has a moderate potential for the occurrence of base-metal resources in disseminated porphyry deposits. The Triplets, a large breccia pipe structure located along strike just northeast of the study area, may also contain resources of base metals in a deposit analogous to that found at the Royal Development mine (see area C-3, fig. 5).

Area C-6 contains a granitic plug that intruded gneiss. A pyritic halo weathers to form a pronounced red color anomaly. Geochemical anomalies surrounding the plug indicate possible base-metal mineralization (see discussion of area B-6). A weak propylitic-alteration halo is present. Little exploration work has been done. We have classified the area as one of low potential for the occurrence of base-metal resources in a porphyry deposit, although further work may prove that the area warrants a higher resource classification.

Area C-7, the Goff prospect, surrounds a Tertiary plug of dacitic rock having a strong gravity high. Geochemical anomalies are widespread, but they are particularily strong along an east-west fracture zone near the wilderness boundary. This area has a moderate potential for the occurrence of base-metal resources in a disseminated porphyry deposit.

Many less well defined geochemical anomalies of base metals occur throughout the study area, but existing data are not sufficient to warrant discussion of the mineral potential of these areas (see Church and others, 1982; Grant, 1982; Stotelmeyer and others, in press).

D. Volcanogenic massive-sulfide deposits

Volcanogenic massive sulfides, predominately pyrite or pyrrhotite deposits with associated chalcopyrite, sphalerite, and galena, form in belts of submarine volcanic rocks. Gold and silver are commonly substantial coproducts (Singer and others, 1982). Features of volcanogenic massive-sulfide deposits are described by Franklin and others (1981). In the geologic environment where island arcs occur along continental margins, basalt and lesser amounts of andesite and dacite are interbedded with clastic deposits, tuffs, ferruginous cherts, and carbonate sediments. The sulfide deposits are stratabound, and mineralogical banding results from primary deposition of sulfides on the sea floor. Hydrothermal alteration is largely confined to the small feeder zone, resembling a stockwork, below the deposit (see the description by Kinkel and others, 1956, of the stockwork exposed at the Mammoth mine in the West Shasta district of northern California). Chlorite and silica and sericitic alteration zones may surround massive-sulfide deposits, and then a larger, more easily detected, geochemical anomaly may result (Sangster, 1972; Doe, 1982). Geochemical anomalies, however, are generally subtle; zinc, barium, and either copper or silver may be found in the stream sediments. Heavy-mineral concentrates may contain barite, pyrite, pyrrhotite (found in the magnetic separate), and, rarely, chalcopyrite and sphalerite. Geochemical anomalies detected in heavy-mineral concentrates may include cobalt, mercury, and gold in addition to those elements anomalous in stream sediments. Generally, geophysical methods are useful in prospecting for massive-sulfide deposits because they are characterized by both a magnetic and a gravity contrast; electromagnetic methods have also been successful.

The pre-Tertiary metamorphic rocks in the east-central part of the study area are part of a belt of late Paleozoic oceanic sediments and island-arc volcanic rocks that are now preserved in thrust sheets north of the study area (Misch, 1966, pl. 1). This series of rocks was mapped by Cater and Crowder (1967) and Cater and Wright (1967) as the younger gneissic rocks of the Holden area. Detailed mapping (DuBois, 1954) of the area near the Holden mine, done in conjunction with company geologists, indicated abundant amphibolite and calc-silicate lenses. A brief summary of the geology of the Holden mine was presented by Youngberg and Wilson (1952). Amphibolites and metavolcanic rocks are more abundant in the geologic section near the Holden mine than to the north. Mattinson (1972, p. 3773) gave a late Paleozoic age of 265±15 m.y. for the metavolcanic rocks.

Ores of the Holden mine are stratabound and zoned; gold values parallel copper (chalcopyrite) content, and silver values peripheral to the chalcopyrite zones show a crude correlation with zones of iron-rich sphalerite and minor galena (Frank Ebbutt, unpub. data, 1938; Youngberg and Wilson, 1952). Magnetite is common; molybdenite and radioactive minerals are rare. DuBois (1954) described a conformable lens of anhydrite and numerous lime-silicate lenses that parallel the layering of the amphibolite in the Holden mine. We interpret these lenses as volcanic-exhalite layers intercalated with carbonate sediments deposited on the flanks of a submarine volcanic center. These characteristics (see table 6) suggest that the deposit at the Holden mine is a massive sulfide of late Paleozoic age that was subsequently metamorphosed to amphibolite grade (Nold, 1981). Sulfide stringers indicative of volcanogenic massive-sulfide deposits also occur to the north at the Mary Green deposit (see table 2), where workings expose a small pyrrhotite-rich zone. Grant (1982) states that these rocks can also be traced northwest into the Company Creek drainage basin (see the discussion of the Goericke prospect in the previous section). Studies of the Holden mine and tailings indicate resources in both (see table 1). Exploratory drilling during the late 1950's failed to prove additional ore reserves at depth. Recovery of precious metals and zinc from the mill tailings is not cost effective at this time.

The Holden belt (area D-1, fig. 6) is defined largely on the basis of geochemical anomalies and

Table 6.--Summary of data for the volcanogenic massive-sulfide-deposit model

[Field observations: +, feature observed; ?, field observations not made or inconclusive. Geophysical anomalies: H, high; ?, no indication. Potential for occurrence of mineral resources: M, moderate. Minerals: Py, pyrite; Sch, scheelite; Ti-m, titanium minerals; Tour, tourmaline]

Recognition criteria	Holden belt (area D-1)
1. Regional geologic setting	
A. Island-arc setting	+
2. Geologic environment	
A. Basalt>felsite	+
B. Calcarous sediments	+
C. Ultramafic associations	+
D. Exhalative layers	+
E. Iron-rich chert layers	?
F. Conformable, tabular sulfide strata	?
G. Gossans	+
H. Alteration	? (sericite schist)
3. Geochemistry	
A. Anomalous metals in stream sediments	Zn, Mo, Au, Ni
B. Anomalous acid-soluble metals in stream sediments	Nb, Mo, Cu, Zn, Co, Sr, Ni, Mn, Ti
C. Anomalous metals in panned concentrates	Cu, Mo, Mn, Ba, Sn, W, B
D. Mineralogy of heavy-mineral concentrates	Py, Sch, Ti-m, Tour
E. Anomalous halo elements in rocks	Ba, Zn, Co, Cu
F. Anomalous commodity elements in rocks	Ag, Au, Zn, Pb, Mo, Cu
4. Geophysics	
A. Magnetic indication	H
B. Gravity indication	?
5. Mining activity summary	
A. Known deposits	Holden mine ([1]#23, [2]G-Holden mine zone), Cu, Au, Ag, Zn
B. Mineral occurrences or zones containing possible undiscovered resources	Mary Green ([1]#29, [2]G-16), Cu, Ag
C. Number of prospects, workings, and the like (excluding 5A)	6
D. Resource assessment	M

[1]Stotelmeyer and others (in press).

[2]Grant (1982).

geologic evidence. The outcrop pattern of the Holden schist and gneiss belt is roughly coincident with a regional zinc anomaly and sporadic gold, nickel, and molybdenum anomalies. However, these geochemical signatures may reflect, in part, Tertiary events along the Glacier Peak transverse structure of Grant (1969). Dikes of Tertiary(?) granodiorite porphyry occur in the Holden mine and on the ridge near the Mary Green prospect. A strong geochemical anomaly occurs immediately south of the Holden mine in the headwaters of the Entiat River (Church and others, 1983a, b) and is associated with Tertiary igneous activity. More detailed studies are needed to locate concealed deposits in the belt and to map the felsic and mafic volcanic units in the younger gneisses of the Holden belt. Area D-1 has a moderate potential for the occurrence of copper, zinc, gold, and silver resources in volcanogenic massive-sulfide deposits, on the basis of our current geologic data.

E. Gold-bearing quartz-vein deposits in metamorphic host rocks

Gold-bearing quartz veins are a common occurrence in greenstone belts of folded and metamorphosed continental margins such as the Abitibi belt of Canada (Boyle, 1979; Fryer and others, 1979) and the mother lode of the Sierra Nevada (Knopf, 1929). Quartz veins are associated with fractures or faults in the rocks. These deposits have anomalous gold, silver, arsenic, antimony, copper, and, locally, chromium signatures in stream sediments (Bohlke, 1982). Heavy-mineral concentrates may include gold, cinnabar, arsenopyrite, galena, sphalerite, stibnite, and sulfosalts. The chromium-rich micas occur in association with carbonates, commonly with dolomite, in this environment. Mercury, lead, zinc, and copper may occur as geochemical anomalies in the heavy-mineral concentrates as well as those elements anomalous in the stream sediments.

The general geologic indications for the presence of gold-bearing quartz veins have not been observed in the study area. However, area E-1 (see fig. 6), defined by the Chaval pluton in the northwestern part of the study area, contains the correct geochemical signature for this type of deposit. Alternatively, it also may be classified as a hydrothermal-vein deposit that should be considered under section B. The pluton is dioritic to tonalitic in composition (A. B. Ford, unpub. data, 1982; Ford and others, 1983) and has been metamorphosed. Gold anomalies occur in stream basins containing large quartz clasts, but the source veins were not found in outcrop. We have classified the outcrop area of the Chaval pluton as an area of low potential for the occurrence of gold resources in hydrothermal quartz veins.

Other areas of metamorphosed mafic volcanic rocks in the study area, namely the Holden area discussed in the previous section, are not probable areas where this model would be applicable because of the high metamorphic rank. Free gold, however, was separated from quartz-rich pods in the migmatitic Skagit Gneiss east of the Holden mine (see fig. 6), indicating that metamorphic concentration of gold may make this terrane a good source for gold in placer deposits.

F. Igneous cumulate deposits

Layered ultramafic complexes are sources of nickel, cobalt, chromium, and platinum-group metals. Nickel sulfides may be deposited near the base of layered mafic bodies (Foose, 1982). Stratiform chromite lenses also are common, for example, in the Stillwater Complex in Montana, where chromite pods occur in the lower third of layered igneous complexes (Jackson, 1968; Lipin and Page, 1982). Platinum-group metals may occur with chromite (McLaren and DeVilliers, 1982), or platinum-rich zones may also accumulate in the upper part of layered igneous complexes (Todd and others, 1982).

Two mafic igneous rock units occur in the study area. The Riddle Peaks pluton (F-1, fig. 6), north of Holden, is a hornblende gabbro. No ultramafic sequences are exposed. Reconnaissance geochemical studies of samples from this body (R. R. Carlson and E. F. Cooley, unpub. data, 1982) indicated no detectable platinum-group metals. Detailed mapping and geochemical studies necessary to delineate possible platinum-group metal deposits in the pluton are outside the scope of this study. The body is associated with a pronounced magnetic anomaly (Flanigan and others, 1983). Assessment of possible mineralized rock at depth by drilling was beyond the scope of this study. The area F-1 is assigned a low potential for the occurrence of nickel, cobalt, chromium, and platinum-group metal resources in magmatic segregations of mafic layered complexes.

Small bodies of ultramafic rocks are found in the central schist belt; geochemical studies indicate anomalous chromium, cobalt, and nickel in drainage basins confined either to the schist belt or in drainage basins along the Straight Creek fault west of the study area. Most of the ultramafic bodies are only tens to hundreds of feet long; the largest bodies of ultramafic rock found in the area are on Spire Point (Grant, 1966), north of Glacier Peak (F-2, fig. 6), and along the White River, south of the study area (Ford and others, in press). Because of the small size of the ultramafic bodies and their discontinuous nature, the area of the central schist belt has a low potential for the occurrence of nickel, cobalt, chromium, and platinum-group metal resources in pod-shaped deposits.

G. Placer deposits

Placer deposits are possible where gold, platinum, or heavy minerals such as garnet can be concentrated by hydraulic means in streams. No evidence for gold placers was found in the study area during either the geochemical reconnaissance or during specific studies for gold placers (Stotelmeyer and others, in press). The Railroad Creek drainage basin, below the Holden mine (see fig. 6), empties into Lake Chelan before any suitable change of stream gradient is encountered, and the area near the Glacier Peak deposit drains directly into the Suiattle River where a placer deposit would be difficult to find and work. Therefore, the study area has a low potential for the occurrence of placer-gold resources.

Potential for nonmetallic resources

Nonmetallic commodities examined during this study include pumice and cinder, marble, garnet, and,

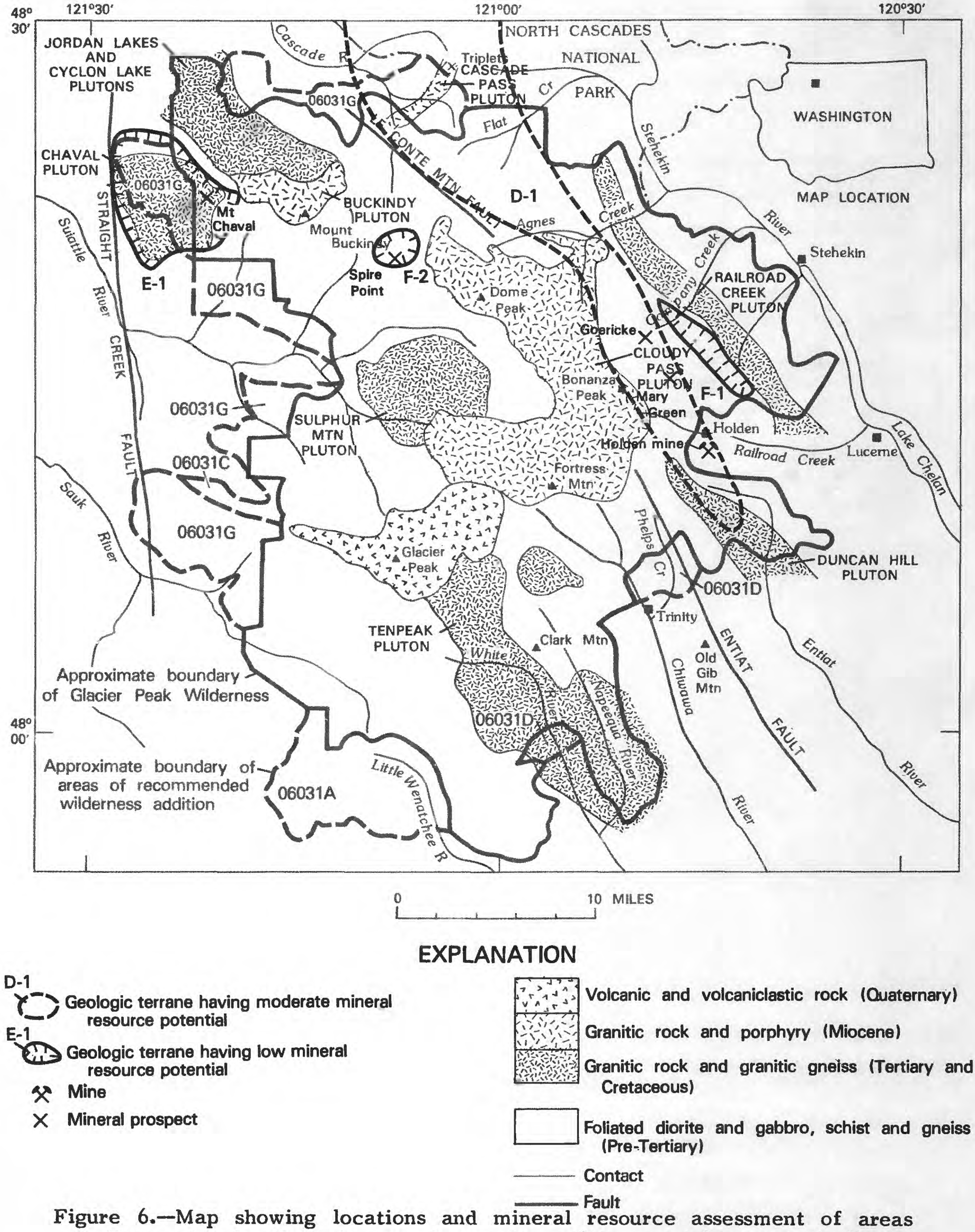


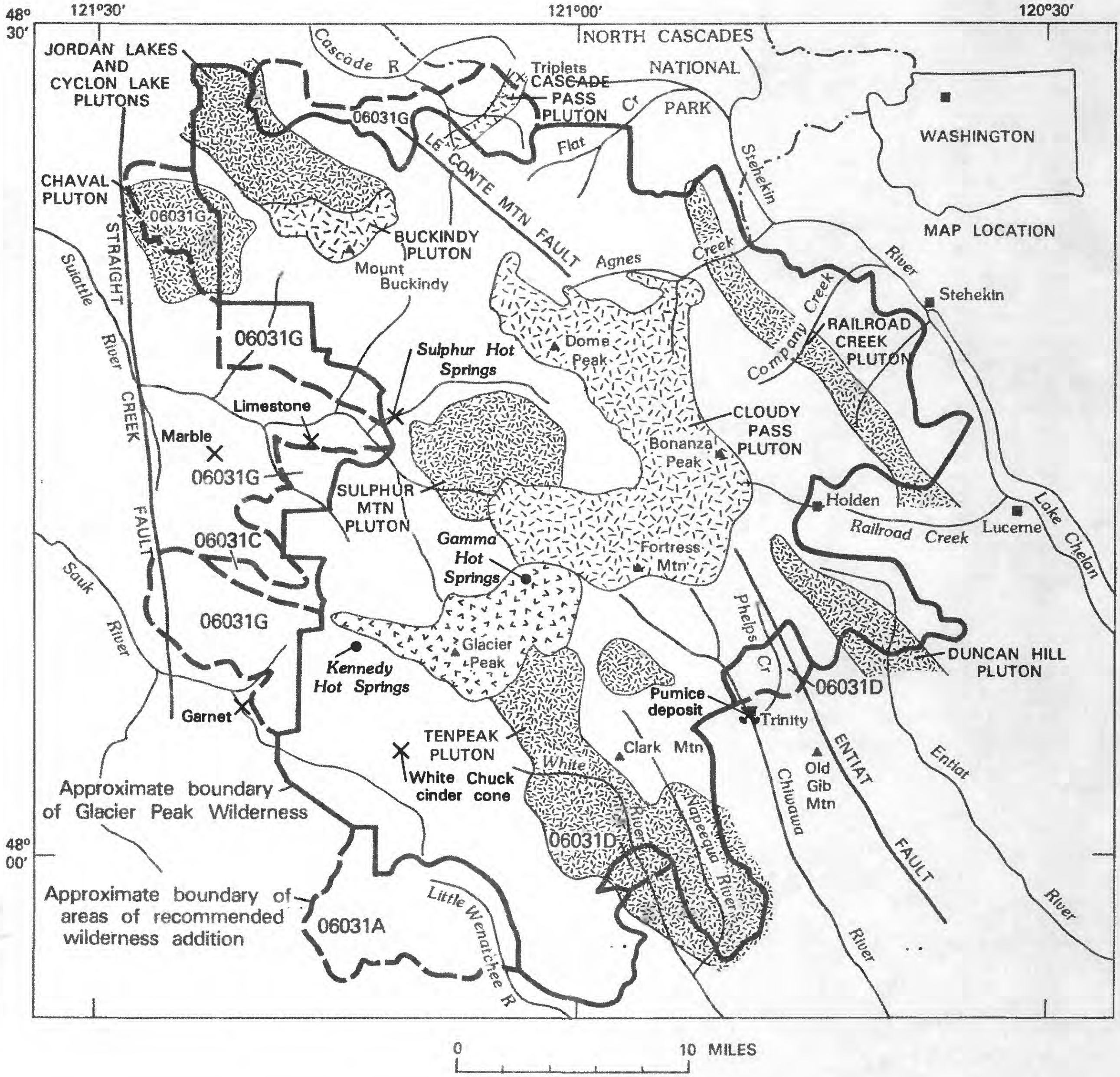
Figure 6.—Map showing locations and mineral resource assessment of areas discussed under the volcanogenic massive-sulfide model (D, see table 6), the metamorphic-hosted, gold-bearing quartz-vein model (E), the igneous-cumulate model (F), and the placer model (G).

Table 7.--Locations of nonmetallic resources in and near the Glacier Peak Wilderness and adjacent areas, Chelan, Skagit, and Snohomish Counties, Washington

[Leaders (--) indicate that deposit is too widespread to be shown on map by number]

No. on map[1]	Property	Type	Tonnage (except where noted)	Resource[2] classification	Commodity	Area
94	White Chuck cinder cone	Pyroclastic	24 million (cubic yards)	Indicated; subeconomic	Volcanic cinders	Wilderness
--	Pumice deposits	Pyroclastic accumulations	Not available	Numerous deposits, some of which have had production, in upper Chiwawa and Entiat River basins	Pumice	Wilderness
67	Chiwawa River pumice (study area only)	Pyroclastic	5.2 million (cu yd)	Inferred; marginal reserve	Pumice	06031D
99	Circle Peak - Meadow Mountain	Marbleized limestone	100 million	Inferred; subeconomic	Limestone	adjoins area 06031G
98	Lime Mountain	Marble	400 million	Inferred; subeconomic	Limestone	adjoins area 06031G
96	Garnet Creek - Ruby Creek (two adjacent deposits)	Garnet placer	2,000	Inferred; marginal reserve	Garnet	adjoins area 06031G

[1]Numbers correspond to locations on accompanying map, MF-1652-A.
[2]U.S. Bureau of Mines and U.S. Geological Survey (1980).



EXPLANATION

- × Mineral prospect
- ⚒ Quarry
- ● Hot Springs

- Volcanic and volcaniclastic rock (Quaternary)
- Granitic rock and porphyry (Miocene)
- Granitic rock and granitic gneiss (Tertiary and Cretaceous)
- Foliated diorite and gabbro, schist and gneiss (Pre-Tertiary)
- Contact
- Fault

Figure 7.--Map showing locations of nonmetallic commodities (see table 7).

as possible byproducts of the mill tailings at the Holden mine, pyrite and silica. Other nonmetallic resources not examined might include sand and gravel, talc, soapstone, kyanite, and feldspar. Identified resources for several of these commodities are given in table 7. Nonmetallic resources in the study area include volcanic cinders at the White Chuck cinder cone and pumice from widespread deposits in the upper Chiwawa and Entiat River basins in the Glacier Peak Wilderness. A large pumice deposit also occurs just south of, but extends into, area 06031D; there has been minor production from this deposit (see fig. 7; table 7, no. 67). No production of pumice can be expected from other remote deposits within the study area. Nonmetallic commodities occurring adjacent to area 06031G consist of subeconomic deposits of marble and placer deposits of garnet.

Sand and gravel are abundant, but adequate resources exist outside the study area. Although some talc is produced just northwest of the study area, talc production from the small metaperidotite bodies in the central schist belt is not considered practical because of the sparse distribution and low grade of the occurrences. A feldspar deposit is under development near the southern border of the study area; an evaluation of feldspar potential was not made since no large pegmatitic bodies were found in the igneous or metamorphic terranes. A low potential for nonmetallic resources is indicated for the study area.

Potential for energy resources

The potential for the occurrence of geothermal resources must be considered in an area containing a dormant volcano such as Glacier Peak. Obvious indications of present and recent thermal activity in the wilderness are the three hot springs (fig. 7) and 17th- or 18th-century ash deposits from the Glacier Peak volcano (Beget, 1982). No fumarolic activity at Glacier Peak has been recorded since about 1900. Thermal-spring temperatures are: Kennedy Hot Springs, 35°C (95°F); Sulphur Hot Springs, 37°C (99°F); and Gamma Hot Springs, 65°C (149°F) (Mariner and others, 1982). Chemical geothermometers (Mariner and others, 1982) suggest the following aquifer temperatures: Sulphur, 110-117°C (230-243°F); Kennedy, 145-189°C (293-372°F); and Gamma, 178-216°C (352-421°F). Such temperatures, particularly that of Gamma Hot Springs, suggest a potential for the occurrence of a geothermal resource; however, these are indirect estimates, and none of the springs are associated with siliceous sinter, a general indicator of high subsurface temperature (Mariner and others, 1982). Gamma Hot Springs has been evaluated as a small hot-water convection system having reservoir temperatures greater than 150°C (302°F) (Brook and others, 1979, p. 56-57). Discharges from at least six small orifices in and near Gamma Creek, near a small but presently inactive travertine deposit, are in an extensive area of hydrothermally altered volcanic rock in which the alteration does not appear related to present hot-spring activity (T. E. C. Keith, written commun., 1982). The host rock is older than the lavas of the Glacier Peak volcano and may have erupted from the underlying tonalitic Cloudy Pass pluton in Miocene time (Tabor and Crowder, 1969). The size of the altered area suggests a relation either to the Cloudy Pass pluton or to more extensive, earlier hot-spring activity. A low potential for geothermal resources exists near the north and west sides of Glacier Peak in the Gamma Hot Springs area. Detailed hydrologic and heat-flow investigations and drilling would be required for a comprehensive evaluation of the geothermal potential. The rugged terrain, lack of roads, and remote location would hinder possible development of such resources.

No source beds for oil and gas occur within the study area, which is almost entirely underlain by igneous and metamorphic rocks and by volcaniclastic sediments (Ford and others, in press). Furthermore, no structural traps have been identified in rocks that have not been heated above the breakdown temperature of hydrocarbons. We consider the study area to have a low potential for the occurrence of oil and gas resources.

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