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RECONNAISSANCE GEOCHEMICAL SURVEY OF GULLY AND STREAM SEDIMENTS, AND GEOLOGIC SUMMARY, IN PART OF THE OKANOGAN RANGE, OKANOGAN COUNTY, WASHINGTON

By
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IN COOPERATION WITH THE
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By
C. DEAN RINEHART 1/

ABSTRACT

A reconnaissance geochemical stream-sediment sampling survey was conducted in a 1,150-km^2 (440 mi^2) area in the central part of the Okanogan Range, adjacent on the west to a 2,000-km^2 (800 mi^2) area previously studied. About 75 percent of the bedrock is composed of a mosaic of elongate northwest-trending Mesozoic plutons, the average composition of which is probably granodiorite. These intrude a highly recrystallized eugeosynclinal assemblage of Paleozoic and Mesozoic age that makes up about 15 percent of the area. The remaining 10 percent consists of andesite and dacite flows and flow breccias of Tertiary age that unconformably overlie the older rocks. The entire area is irregularly mantled by glacial drift.

Most of the productive mines of the Conconully mining district are quartz fissure vein deposits that occur in an area of about 100 km^2 (40 mi^2) in the southern part of the area studied. They have yielded silver, lead, and copper ore valued, at times of production, at about one-third of a million dollars. Most of the mining activity took place late in the last century. These deposits seem to be related in a general way to the contact between a granodioritic pluton and its metamorphic wall rock and are about equally distributed between the two units.

A total of 340 gully- and stream-sediment samples collected from 249 localities were analyzed colorimetrically for cold-acid-extractable copper (xCu) and citrate-soluble heavy metals (cxHm), and for 30 elements by standard semiquantitative spectrographic methods. All samples were also analyzed for gold by the atomic absorption method. Values obtained by both of the colorimetric methods, together with isopleths, were plotted on overlays for the geologic map to emphasize localities or areas where such values are anomalously high and are equal to or exceed selected threshold values of 10 ppm xCu and 10 ppm cxHm. The two most impressive anomalies, not surprisingly, are associated with known mineralized terrane, but several other anomalous or subanomalous xCu and cxHm highs are in terrane not previously known to be mineralized. In addition, spectrographic analyses show that silver values, at least locally, persist farther downstream than xCu or cxHm, where all three are anomalously high at or near known mineralized ground. Several scattered sample localities that show low-level silver values are either isolated or marginally related to subanomalous cxHm highs. Further geochemical exploration, in addition to seeking mineralized source terrane for unexplained xCu and cxHm anomalies, should probably also include more sensitive tests for silver, such as atomic absorption, in the light of the apparent enhanced downstream persistence of this metal over both copper and heavy metals.

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INTRODUCTION

This report presents the results of geochemical sampling of gully and stream sediments in the context of their geologic setting in a part of the Okanogan Range in north-central Washington, including the historic Conconully-Ruby mining district. The area adjacent on the east was similarly sampled and described by Fox and Rinehart (1972). Those interested in that report likely will also be interested in a report by Marjaniemi and Robins (1975) on the results of a reconnaissance investigation of uranium in Tertiary sedimentary rocks in the western Okanogan Highlands and the upper Columbia River valley. Besides extensive data on uranium, thorium, and potassium, that report also includes spectrographic analyses for 34 elements for more than 300 samples. The area covered by the map in the present report (fig. 1) is a little less than 1,300 km^2 (500 mi^2), about 150 km^2 (60 mi^2) of which overlaps with the area previously studied in order to include the Conconully-Ruby mining district on a single map. The geochemical sampling program is part of a broader study of the geology and mineral deposits of part of Okanogan County sponsored jointly by the U.S. Geological Survey and the Washington Division of Geology and Earth Resources. In order to aid the reader in interpreting the geochemical data, the geologic setting is discussed in some detail.

FIGURE 1.— Index map of Washington, showing location of plate 1, in a part of the Okanogan Range, north-central Washington.

The area covered includes a segment of the rugged backbone of the Okanogan Range, which is less accessible than the foothills and dissected plateau of the Okanogan Highlands, adjacent on the east. Because the sampling was of a reconnaissance nature, first-order approximation of metal distributions and abundances was considered sufficient. Lengthy foot traverses to obtain samples were considered impracticable, and the sample coverage is somewhat spotty. Nevertheless, the data gained are potentially useful in the search for metalliferous deposits. Details of the sampling scheme, technique, and rationale used in this study are similar to those used in the sampling program in the area to the east (Fox and Rinehart, 1972) and are not repeated here.

The work of Menzer (1965) and Hibbard (1971) was used in compiling the geologic map and in summarizing the geology in their respective areas. In addition, an area studied by Goldsmith (1952) lies within the area mapped by me, and his work contributed much to my own understanding of the geology. The nomenclature of these workers is followed except where changes were required to fit the more generalized units used in this report and to follow nomenclature already established in areas adjacent on the east. Contacts at the east margin of Hibbard's area (see pl. 1) were modified to fit similar contacts along the west margin of the Loomis quadrangle (Rinehart and Fox, 1972; Fox and Rinehart, 1972; Rinehart and Fox, 1976).

SUMMARY OF BEDROCK GEOLOGY

Bedrock in the area consists chiefly of Permian and Triassic metamorphic rocks; Triassic, Jurassic, and Cretaceous plutonic rocks; and

Tertiary volcanic rocks. The metamorphic rocks occupy about 15 percent of the map area and are most abundant in the southeast half. They were probably derived mainly through recrystallization of a eugeosynclinal assemblage composed of siltstone, sandstone, mafic and intermediate igneous rocks, and carbonate rocks, in probable order of decreasing abundance. Except for a volcanic terrane of about 90 km^2 (35 mi^2) in the center, the remainder of the map area is occupied by elongate plutons ranging in composition from diorite to quartz monzonite, including one large body of trondhjemite (leucocratic quartz diorite with oligoclase as chief feldspar).

METAMORPHIC ROCKS

METASEDIMENTARY AND METAVOLCANIC ROCKS

Quartzofeldspathic biotite schist and gneiss predominate within a metamorphic assemblage that also includes, in decreasing abundance, amphibolite, quartzite, marble, and calc-silicate rocks, most of which are also schistose, and a wide variety of hornfels and granofels. Locally, the rocks are migmatitic, and in areas adjacent to granitoid gneiss, the contact is gradational. Marble and calc-silicate hornfels and granofels, collectively, compose the only lithologic type in this unit that is shown separately on the geologic map. They are abundant only in the area northwest of Conconully, near the center of the map, where they form a northwest-trending lentil 6 km (4 mi.) long and less than a kilometer wide.

The high degree of recrystallization and migmatization, together with the absence of marker horizons, makes it virtually impossible either to establish the stratigraphic thicknesses represented in the metamorphic terrane or to correlate these rocks with less metamorphosed rocks of known age to the northwest and east. Nevertheless, rocks of this unit in the northern part of the map area are coextensive with the Kobau Formation of Permian or Triassic age to the east (Rinehart and Fox, 1972, p. 20). Near Sinlahekin Creek, in the east-central part of the map area, rocks of this unit are coextensive both with rocks of the metamorphic complex of Conconully, of Triassic age, and the Anarchist Group of Late(?) Permian age. Near Dunn Mountain in the southeastern part of the map, this unit overlies the Cave Mountain Formation of Triassic age (Rinehart and Fox, 1976). It is certain, therefore, that the range in age represented by the metasedimentary and metavolcanic rocks unit extends at least from Late Permian to Late Triassic.

CAVE MOUNTAIN FORMATION

The Cave Mountain Formation crops out in the southeastern part of the map area and forms the western extremity of a metamorphic terrane made up of five distinct units. This formation, mainly metalimestones and metadolomites, is between 1,200 and 1,500 m thick and occupies an area of approximately 80 km^2 (30 mi^2), most of which is east of the map area (Rinehart and Fox, 1976). The rocks probably are partly correlative with the Kobau Formation of Permian or Triassic age (Rinehart and Fox, 1972, p. 20-22). They unconformably overlie the Anarchist Group (Rinehart and Fox, 1972, p. 10-11) of Late(?) Permian age. One unit yielded diagnostic fossils of Late Triassic age (Misch, 1966, p. 118).

METAMORPHOSED MAFIC AND ULTRAMAFIC ROCKS

Metamorphosed mafic and ultramafic rocks occupy a few square kilometers in the extreme northeastern corner of the map area. They were previously described by Hibbard (1971, p. 3026-

3028) as the Chopaka intrusive complex. One of the bodies of mafic rocks is continuous into the Loomis quadrangle to the east, where it was mapped as equivalent to and part of the Palmer Mountain Greenstone, owing to its close physical and chemical resemblance to rocks typical of that unit (Rinehart and Fox, 1972, p. 11-13).

The mafic rocks are composed of extensively recrystallized and sheared metagabbro that consists of calcic plagioclase and actinolitic hornblende. They exhibit varied textures and structures ranging from layered gneiss to more massive, sheared, irregularly textured types.

Similarly deformed, unzoned, partly serpentinized dunite is the dominant rock of the ultramafic part of the complex. Typically, it is composed of olivine, enstatite, and diopside, along with abundant talc and serpentine and local small pods of chromite. Actinolitic hornblende from the westernmost mafic mass yielded a K-Ar age of 190.5 ± 15.6 m.y. (Hibbard, 1971, p. 3045). Because the mineral dated is of metamorphic origin, its age presumably dates a Late Triassic metamorphic event.

METAGRANITOID ROCKS

Metagranitoid rocks, with a configuration and internal structure generally parallel to the regional northwest structural grain, occupy a few square kilometers in the southeastern part of the map area. The rocks range from quartz diorite to quartz monzonite and probably average granodiorite. Although most of the rocks are almost exclusively gneissic, others are layered or are conspicuously porphyroblastic with planar-oriented tabular K-feldspar porphyroblasts as much as 5 cm long. The local preservation of intrusive contact relations with wall rocks, the contrast in texture with rocks of the adjacent metasedimentary and metavolcanic terrane, and the local preservation of relict zoning in plagioclase indicate a magmatic origin for these rocks. Though clearly younger than their intruded wall rocks, which are probably not younger than Late Triassic, the metagranitoid rocks have also been metamorphosed. The closest, oldest unmetamorphosed rock is the granodiorite of the Conconully pluton, which is approximately 85 m.y. old; therefore, the intrusion of the metagranitoid rocks took place between the Late Triassic and Late Cretaceous.

MESOZONAL IGNEOUS ROCKS

About 80 percent of the map area is occupied by mesozonal plutonic rocks that range in composition from quartz monzonite and trondhjemite to quartz diorite and probably average granodiorite. Of the 18 plutonic units distinguished on the map (pl. 1), 9 have been dated radiometrically and range from Late Triassic to Late Cretaceous. Contacts vary from sharp, simple crosscutting relations to gradational migmatitic zones, tens of meters wide. Some hybrid plutonic rocks clearly show gradation to paragneiss, suggesting that anatexis played a significant role in local plutonism. The salient features of the individual plutonic units are summarized in table 1.

CONGLOMERATE AND SANDSTONE

One small outcrop of massive conglomerate and sandstone is exposed about a quarter of a mile southeast of the southeasternmost extremity of the andesite and dacite unit (in sec. 31, T. 37 N., R. 25 E.). The unit is composed of virtually massive, sand-, gravel-, and boulder-size detritus, derived mainly from granitic and metamorphic rocks. Local weak parting(?) that strikes approximately north and dips gently west may represent bedding. Thin unmapped conglomerate and sandstone beds exposed at the base of the andesite and dacite unit about a mile to the northwest resemble and are probably correlative with this unit.

TABLE 1.—*Plutonic rocks*

Name and map symbol	Composition	Internal structure	Contact relations	Relative and radiometric age
Similkameen composite pluton Jsg	Average, granodiorite; range: quartz diorite (tonalite) to quartz monzonite. Contains euhedral hornblende and sphene; K-feldspar phenocrysts show Carlsbad twins. Color index about 13	Chiefly massive; minor local hornblende and K-feldspar alinement	Shows some wall rock assimilation. Dikes cut metagabbro on Chopaka Mountain, and metasedimentary and metavolcanic rocks; gradational with Horseshoe Mountain pluton (stated in Hibbard, 1971, p. 3032, but not shown as gradational on his map)	Dikes cut metagabbro on Chopaka Mountain; K-Ar mineral ages from granitic rocks and cogenetic, peripheral alkalic rocks of the composite pluton, all east and northeast of plate 1, range from 70 m.y. to 177 m.y.; the true age of the pluton is probably between 177 m.y. and 191 m.y. (Fox, Rinehart, and Engels, 1975)
Horseshoe Mountain pluton Mzhm	Homogeneous medium- to coarse-grained porphyritic quartz monzonite; contains clustered quartz crystals and irregularly distributed K-feldspar phenocrysts as much as 5 cm long. Color index about 5	Massive	Gradational with Similkameen pluton, sharp with Tillman Mountain pluton	Apophysal dikes cut Tillman Mountain pluton
Cathedral pluton Kc	Similar to Horseshoe Mountain except non-porphyritic; miarolitic cavities containing euhedrally terminated quartz crystals. Color index about 4	Massive	Commonly sharp with Tillman Mountain pluton; also gradational with it through mapped hybrid and gneissic, migmatitic zones	Apophysal dikes cut Tillman Mountain pluton, K-Ar biotite ages of 94.0±2.8 m.y. (Hawkins, 1968, p. 1789); 97.7±2.9 (Engels and others, 1976)

TABLE 1.—*Plutonic rocks—Continued*

Name and map symbol	Composition	Internal structure	Contact relations	Relative and radiometric age
Tillman Mountain pluton Mzt	Highly varied, generally quartz diorite or granodiorite; hybrid textures not uncommon, particularly in southern part; typically medium-grained. Color index about 22	Commonly gneissose, locally massive	Sharp with Horseshoe Mountain and Cathedral plutons; also locally sharp with diorite and gneissic migmatite in the north; gradational with Loomis and monzonite plutons; contact with latter commonly grades through mapped hybrid zone; grades to paragneiss at south end	Cut by dikes of Horseshoe Mountain and Cathedral plutons; also cut in northern part by diorite and by unmapped gneissic migmatite
Anderson Creek pluton Kac	Granodiorite, fine- to medium-grained; local fine- to medium-grained dioritic border phase; local pink poikilitic K-feldspar phenocrysts. Color index about 8	Massive	Typically sharp with all wall rocks	Cuts Loomis pluton. K-Ar biotite age 106.5±6.8 m.y. (Hibbard, 1971, p. 3045); K-Ar biotite 100.1±3.0, hornblende 115.6±3.0 (Engels and others, 1976)
Diorite, quartz diorite, and gabbro Mzd	Gabbro (on Chopaka Mountain), quartz diorite (north-central part of map), several small dioritic bodies in southern part of map; grain size ranges from fine to coarse: Color index about 30	Massive	Commonly sharp, locally gradational, especially with Anderson Creek pluton; shows local evidence of magmatic stoping and assimilation	Cuts Tillman Mountain and Loomis plutons

TABLE 1.—*Plutonic rocks—Continued*

Name and map symbol	Composition	Internal structure	Contact relations	Relative and radiometric age
Hybrid granitoid rocks Mzh	Highly varied in composition and textures; grain size fine to coarse; average composition is probably granodiorite, and textures are typically gneissose with variation to both hypautomorphic-granular and granoblastic. Color index highly varied	Commonly gneissose, and migmatitic; locally massive	Gradational with the Tillman Mountain and monzonite plutons in the northern part of the map area, and with the gneissic trondhjemite of Tiffany Mountain, and Old Baldy and Lone Frank plutons in the southern part; fairly sharp with metamorphic rocks; sharp with Bottle Spring and Conconully plutons	Northern mass interpreted by Hibbard (1971, p 3033) as resulting from syntectonic intrusion of magma equivalent to monzonite and leucocratic monzonite gneisses into Tillman Mountain pluton; southern mass clearly intruded by the Bottle Spring pluton on the north, and the Conconully pluton on the south
Toats Coulee pluton (North Fork Camp hybrid gneiss of Hibbard, 1971; that is, continuous to the east with Toats Coulee pluton, of Rinehart and Fox, 1972, in the Loomis quadrangle) Jtc	Markedly varied in composition and texture, but average composition is probably granodiorite and average texture hypautomorphic granular. Dioritic border phase on northeastern and eastern margin not shown on plate 1. Porphyritic varieties common toward the east; gneissic, migmatitic, and hybrid rocks common elsewhere. Color index highly varied	Gneissose, migmatitic in central and western parts; commonly massive in eastern part	Gradational with Tillman Mountain and monzonite plutons, according to Hibbard; both gradational and sharp with mafic border phase along eastern contact (Loomis quad), which is consistently sharp with Loomis pluton	Cuts Loomis pluton to east in Loomis quad; Hibbard (1972, p. 3033) interprets this unit as derived from syntectonic intrusion of magmas equivalent to monzonite and leucogneiss into Tillman Mountain pluton. K-Ar hornblende age 170±5 m.y.; biotite age 151±5 m.y. (Rinehart and Fox, 1972, p. 52; locality SW$\frac{1}{4}$ sec. 13, T. 39 N., R. 24 E.)

TABLE 1.—*Plutonic rocks—Continued*

Name and map symbol	Composition	Internal structure	Contact relations	Relative and radiometric age
Monzonite pluton Mzm	Average rock contains a little more than 10 percent quartz, hence is quartz monzonite in many classifications; resembles Cathedral pluton; medium- and coarse-grained. Color index about 10	Varied, both massive and gneissose	Gradational with Tillman Mountain pluton and with hybrid granitoid rocks	Interpreted by Hibbard (1971, p. 3033) as younger than Tillman Mountain pluton
Loomis pluton T̄Rl	Composition ranges from quartz diorite to granodiorite; uniformly medium-grained; well-formed to euhedral hornblende and biotite common. Color index about 15	Chiefly massive, locally gneissic along contacts with older rocks	Gradational with Tillman Mountain pluton	Intruded by Anderson Creek pluton. K-Ar hornblende age 194±6 m.y.; biotite age 179±5 m.y. (Rinehart and Fox, 1972, p. 52)
Bottle Spring pluton Mzb	Grades from quartz monzonite in the north to granodiorite in the south; homogeneous; medium-grained. Color index average = 14 (7–25)	Massive	Appears to be abrupt but was not observed in outcrop	Appears to truncate the gneissic structure in the hybrid granitoid body. Possibly intrudes Lone Frank pluton
Lone Frank pluton Mzl	Diorite to quartz diorite, fairly homogeneous in central and eastern parts, highly varied to west; medium-grained. Color index about 30	Typically massive, gneissose near borders	Locally sharp, commonly gradational with surrounding gneisses over many tens of meters	Age relations with surrounding rocks ambiguous

TABLE 1.—*Plutonic rocks—Continued*

Name and map symbol	Composition	Internal structure	Contact relations	Relative and radiometric age
Blue Goat pluton Jbg	Granodiorite, fairly homogeneous, medium-grained, weakly porphyritic. Color index about 22	Commonly weakly to moderately gneissose, especially near wall-rock contacts	Commonly sharp and concordant; locally discordant; gradational with paragneiss at southwestern limit of exposure	K-Ar hornblende age 141.8±2 m.y., biotite age 99.3±3 m.y. (Rinehart and Fox, 1976; Engels and others, 1976)
Granodioritic gneiss of Salmon Meadows Mzs	Granodiorite but with dioritic and quartz dioritic variants; commonly shows variation in composition over short lateral distances; medium-grained. Color index about 25	Gneissic with some irregular layering; locally massive	Are probably sharp (not seen in outcrop) on the west but are obscured and gradational on the east, owing to abundant intrusion of dikes and sills of fine- to medium-grained granodiorite and quartz monzonite, as well as aplite and pegmatite	Age relations not known
Gneissic trondhjemite of Tiffany Mountain Kgt	Mostly trondhjemite (leucocratic quartz diorite with oligoclase as chief feldspar), but locally more potassic near contacts; biotite is chief dark mineral, locally accompanied by hornblende; inhomogeneous near contacts; becomes more homogeneous toward west. Typically medium grained. Color index about 8	Commonly gneissic, especially near contacts where it locally becomes migmatitic; some wispy layering near contacts. Though more massive toward west, some planar structure can usually be found; textures visible microscopically indicate pervasive moderate cataclasis	Appears to be sharp against Bottle Spring pluton, though not seen in outcrop; gradational with the hybrid granitoid rocks; sharp against Old Baldy pluton	Appears to be intruded by rocks of the hybrid granitoid unit and is therefore likely older than Bottle Spring pluton; definitely intruded by Old Baldy pluton. Rb/Sr isochron 104.2±0.5 m.y.; fission track, apatite 76±8 and 92±9; zircon 90±9; Pb-alpha zircon 90±10 (Menzer, 1970). K-Ar determinations from three localities yield minimum ages of 93.5±2.8, 91.7±2.8, 108±3 (Engels and others, 1976). From the foregoing an age assignment of 100±10 m.y. appears to be a reasonable interpretation

TABLE 1.—*Plutonic rocks—Continued*

Name and map symbol	Composition	Internal structure	Contact relations	Relative and radiometric age
Conconully pluton Kcg	Granodiorite, homogeneous, medium- to coarse-grained, locally coarsely porphyritic; biotite is chief dark mineral, but hornblende is typically present in smaller amounts. Color index about 7	Massive	Contact not seen in outcrop; appears gradational with hybrid rocks through mafic phase near Muckamuck Mountain; elsewhere appears to be abrupt. Locally, contact with Old Baldy pluton marked by narrow zone of fairly numerous mafic inclusions; also locally by narrow zone of poorly defined gneissosity	Truncates gneissosity of the hybrid granitoid unit and of the Old Baldy pluton. Radiometric ages are: 89±9, 94±12 m.y. fission-track apatite; 84±8 fission-track sphene; 90±20 Pb-alpha zircon; 81.1±8 Rb/Sr isochron (Menzer, 1970). 72.8 ±4.6, 78.8±2.4 K-Ar hornblende (Engles and others, 1976). Some evidence of degradation of ages progressively eastward suggests that a reasonable age interpretation is about 85±10 m.y.
Old Baldy pluton Kob	Granodiorite, fairly homogeneous, medium- to coarse grained, typically porphyritic with equant K-feldspar phenocrysts as much as 5 cm (2 in) across. Biotite is chief dark mineral, with hornblende generally present in smaller amounts. Zones common in which finer grained mafic and felsic hybrid rocks are mixed with the typical medium- to coarse-grained host. Color index about 12	Typically somewhat gneissic though massive varieties fairly common	Contacts with gneissic trondhjemite of Tiffany Mountain observed only locally and range in character from knife-sharp to gradational through a zone of mixed rock types of varied textures and compositions. Contacts with Conconully pluton, though not seen in outcrop, appear to be similarly varied	Dikes cut trondhjemite and inclusions of trondhjemite observed in Old Baldy pluton near the contact. Gneissosity in Old Baldy truncated by contact with the Conconully pluton. Radiometric ages are: 78±8 fission track, sphene; 129.0±1.8 Rb/Sr isochron (Menzer, 1970); 98.5±3.0 K-Ar hornblende (Engels and others, 1976). Because of field relations and the wide range in radiometric ages, the inferred age probably is between 85 and 100 m.y.

TABLE 1.—*Plutonic rocks—Continued*

Name and map symbol	Composition	Internal structure	Contact relations	Relative and radiometric age
Dunn Mountain pluton Mzdm	Fine- to medium-grained granodiorite average composition, but marked variation	Massive to gneissic	Both concordant and discordant; at one place contact marked by intrusion breccia; locally finer grained near contact, which suggests chilling	Age relative to other plutonic rocks unknown

ANDESITE AND DACITE

A thick pile of generally massive porphyritic andesite and dacite occupies about 85 km^2 (35 mi^2) in the central part of the map area. Measurements of the refractive index of fused samples suggest that compositions range from andesite to rhyodacite. Chemical analyses of the rocks, however, show that they contain 56 to 62 percent silica and thus would overlap the range for both andesite and dacite.

The lowest few tens of meters locally consist of layers of arkosic tuff, which locally are gradational into conglomerate containing pebbles and cobbles of granitic and metamorphic rocks. These layers intertongue with massive dacite breccia containing clasts as large as 25 cm in diameter. Overlying the tuff and breccia is a massive breccia—probably flow breccia—several tens of meters thick, with clasts averaging 2.5 cm or less in diameter. The breccia is overlain by fairly homogeneous, locally columnar, massive, porphyritic dacite, locally as much as 400 m (1,200 ft) thick. The dacite is finely porphyritic with abundant, fairly equant, white- or light-gray plagioclase crystals and less abundant, mostly short black hornblende prisms set in a greenish-, reddish-, or brownish-gray aphanitic matrix. Although the dacite is commonly altered, no metallic mineralization was observed. The andesite and dacite unconformably overlie granitic and metamorphic bedrock. Although both bedding and flow-banding are rare, the rocks appear to dip gently in varied directions.

A sample collected near the southeast margin of the unit gave a K-Ar hornblende age of 42.9 ± 1.3 m.y., equivalent to Eocene (Engels and others, 1976). Lithologically similar volcanic rocks to the east in the Okanogan River valley, although yielding somewhat older radiometric ages (45 to 52), are also Eocene in age (Rinehart and Fox, 1972, 1976).

METAMORPHISM AND STRUCTURE

Mineral assemblages of most of the metamorphic rocks conform to various subfacies of the almandine amphibolite facies of regional metamorphism, except along contacts with plutons where assemblages diagnostic of the hornblende hornfels facies appear (facies nomenclature after Winkler, 1967). Evidence of profound recrystallization is widespread, and in several places (for example, near Coxit Mountain in the central part of the map area) metamorphic rocks grade along strike into the Tillman Mountain pluton. Throughout this wide zone, relic metasedimentary features of certain gneissic rocks become progressively obliterated. Perpendicular to the regional strike, the same metamorphic belt grades westward into hybrid granitoid rocks.

Sparse amounts of minerals indicative of the amphibolite or hornblende hornfels facies, including garnet, sillimanite, andalusite, staurolite, and anthophyllite, occur at widely separated localities in aluminous rocks in the metamorphic terrane. Diopside, also indicative of the amphibolite facies, was found at several places in impure calcareous rocks.

The age of metamorphism is uncertain. Field relations and radiometric age determinations show that it is bracketed by the oldest unmetamorphosed rocks—Anderson Creek pluton 115.6 ± 3.0 m.y., Early Cretaceous—and the youngest metamorphosed rocks—Late Triassic metacarbonate rocks in the southeastern part of the map area (Misch, 1966, p. 118). Data are insufficient, however, to determine whether metamorphism was synchronous throughout the area represented by plate 1.

The main elements of the geologic structure that can be seen on the geologic map are the general north-northwest trends of the elongate plutons, the similar trends of some metamorphic bodies, and the two fairly continuous faults in the southeastern part of the area. The internal structures within both the metamorphic rocks and the more gneissic plutons tend to parallel this regional trend.

GLACIATION

During the Pleistocene, the Okanogan lobe (Flint, 1935) of the Cordilleran ice sheet overrode all but the highest peaks (those above about 7,200 ft) and deposited an irregular blanket of drift throughout the area. More drift was probably deposited in the less rugged southeastern part of the map area than elsewhere. In addition, that area was mapped in greater detail with the result that plate 1 gives a somewhat exaggerated impression of the amount of drift there as compared to that elsewhere. On nearly all but the steepest slopes, however, the drift mantle obscures much of the bedrock on the lower half of most canyon walls to an extent that the contribution of glacial material to the alluvium in all of the stream courses and flood plains is generally large. The influence that this large glacial component had on the magnitude and position of geochemical anomalies is uncertain, although partial concealment, poor definition, and increased downstream dispersal could be expected.

MINERAL DEPOSITS

Most of the mineral deposits in the area are quartz fissure veins that have yielded mainly silver, lead, and copper. Minor amounts of gold, zinc, and molybdenum have also been produced. Most of these deposits are within the loosely defined limits of the Conconully mining district, the subject of a recent report by Moen (1973). As defined by Moen, the Conconully mining district (also known as the Conconully-Ruby mining district) encompasses an area of 1,360 km^2 (525 mi^2); the western and southern limits of the district approximately coincide with the western and southern borders of plate 1, the northern boundary is the township line separating townships 37 and 38, and the eastern limit is the Okanogan River several kilometers to the east (fig. 1). Most of the principal mines of the district are within a few kilometers of Conconully and are shown on plate 1. Only a brief summary of mining activity is presented here. Moen (1973) gives a comprehensive history of the district and more detailed information on the individual mines.

Mining in the Conconully district began in 1886 and reached its peak before the turn of the century. By 1915, many mine workings were already caved or otherwise inaccessible when they were visited briefly by Jones (1916). The apparent highly irregular and discontinuous distribution of ore minerals within the deposits, declining silver prices, and the lack of a nearby railroad led to the demise of the district probably before production values greatly exceeded a quarter of a million dollars. Activity from 1916 to date has been minor, and it is doubtful that total production ever reached half a million dollars.

Most of the deposits in the Conconully district are in two groups that lie north and south of Conconully. The deposits are very close to the contact between the Conconully pluton and metamorphic wall rocks. A third and smaller group of deposits lies within the Conconully pluton about 2 km from the contact, on the approximate northwestward projection of the fault that follows lower Salmon Creek.

All the veins strike northwest to northeast, with the average strike probably a few degrees west of north, and dip steeply to moderately. They are commonly concordant with internal structures in the host rocks. The most common ore mineral is galena, and pyrite is the most common metallic gangue mineral. Other common ore minerals, listed by Moen (1973, p. 9), in order of decreasing abundance, are tetrahedrite, chalcopyrite, bornite, and sphalerite. Within the veins the ore minerals are commonly concentrated in shoots that are heterogeneously distributed and discontinuous and that typically pinch and swell. Reported maximum vertical extent of the ore bodies is 760 m (2,500 ft) in the Mineral Hill-North Fork area, and 460 m (1,500 ft) at Ruby Hill (Moen, 1973, p. 10).

Of the four deposits shown in the Blue Lake area, 15 km (9 mi) north of Conconully, production is recorded for only the Blue Lake mine (5,000 tons of copper ore in 1901). This is the only vein-type deposit of that group; the other three are described as disseminated copper deposits, all related to intrusive contacts between granitoid and metamorphic rocks (Moen, 1973, p. 33-34).

A deposit of argentiferous galena at the Bernhardt (Carl Frederick) mine, spatially separated from the large group near Conconully, lies 17 km (10½ mi) northwest of Conconully above timber line on the western slopes of Clark Peak, 2½ km (1½ mi) from the Boulder Creek-Tiffany Spring road. More than 300 m (1,000 ft) of workings exist on the property, but there is no record of production.

Huntting (1956) reported a chromite deposit in serpentinite and metagabbro terrane in the steep saddles connecting Chopaka and Joe Mills Mountains and Hurley Peak, north of the Conconully mining district, in the northeast corner of the map area. He described the deposit as consisting of disseminated chromite and chromite concentrations in abruptly discontinuous bands 8 to 10 cm (3 to 4 in) wide, or in 3- or 4-mm (1/8 in) veinlets, in serpentinized dunite. No production is recorded.

A small deposit containing a suite of minerals distinct from others in the district occurs north of the Cecil Creek road in the northern part of the map area in the E½ sec. 14, T. 38 N., R. 24 E. Three small adits, each only a few meters long, explore what appears to be a small metamorphic roof pendant (not shown on pl. 1) composed of quartzite, pelitic schist, and granofels, locally migmatitic, cut by leucocratic granitoid and pegmatite dikes. The pegmatitic zones contain disseminated molybdenite and arsenopyrite, as well as local small pockets, mainly of molybdenite, 1 to 4 cm (½ to 1½ in) long.

GEOCHEMICAL PROGRAM

The objectives of the geochemical exploration program are the same as those established for the area to the east, "to discover and define geographic trends of metallized rock and to locate undiscovered mineral deposits" (Fox and Rinehart, 1972, p. 11). Similar sampling procedures were also followed in order to obtain a few hundred grams of representative sediment from depths of 12 to 25 cm (5 to 10 in) below the surface. Because of poor accessibility, sample coverage is less dense and more irregular in the western and northern parts of the map area than elsewhere. Samples were collected from 249 localities in the initial phase and were sent to a U.S. Geological Survey Field Services Laboratory for analysis. Splits of the -80 mesh fraction, ashed when necessary, were analyzed colorimetrically for cold-acid-extractable copper (xCu) and for citrate-soluble heavy metals (cxHm) using the methods of Canney and Hawkins (1958) and Bloom (1955), respectively. Samples were also analyzed for gold by the atomic absorption method. After analytical results were received, supplementary samples were collected upstream from localities where analysis of the original sample generally showed one or more of the following values, in parts per million: xCu ≥15, cxHm ≥20, Au ≥0.1. On the basis of these criteria, 3 to 8 supplementary samples were collected upstream from each of 25 localities. All samples were subsequently analyzed semiquantitatively by the six-step DC arc spectrographic method.

TABLE 2.—*Colorimetric, semiquantitative spectrographic, and atomic absorption analyses, in parts per million, of a selected group of stream-sediment samples from the Okanogan Range*

[Sample localities shown on plate 1. Colorimetric analysts: cxHm, S. Hoffman; xCu, R. W. Leinz; spectrographic analyst, E. F. Cooley; atomic absorption analyst, A. Wells. Of 25 additional elements determined, none was judged to be present in anomalous amounts, and they are not listed here]

Sample	Colorimetric		Spectrographic (semiquantitative)				Atomic absorption
no.	xCu	cxHm	Cu	Pb	Zn	Ag	Au
[1]T-1	<1	4	20	10	<200	0.5	0.22
[1] 2	2	1	100	20	<200	.5	<.02
3	<1	<0.5	20	1.5	<200	.5	<.02
4	4	<0.5	30	15	<200	.5	.02
5	<1	<0.5	20	10	<200	<.5	.04
34	1	3	30	20	<200	.5	<.02
36	30	14	200	20	700	<.5	<.02
39	<1	3	20	30	<200	.5	<.02
41	<1	2	100	20	300	.5	<.02
[2] 42-B	<1	1.5	30	20	<200	<.5	<.02
[2] 43-B	2	2	70	10	<200	<.5	<.02
47	<1	6	70	10	<200	.5	<.02
48	<1	6	150	10	<200	.5	<.02
49-B	20	7	300	20	<200	.5	<.02
[2] 54	<1	23	100	20	1000	<.5	<.02
56	<1	5	50	10	<200	.5	<.02
92	4	9	70	20	300	.5	<.02
93	<1	10	50	15	300	<.5	<.02
94	10	28	30	50	500	.1	<.02
[2]102	2	2	50	20	200	.5	<.02
103	5	2	50	20	200	.5	<.02
104	1	1	50	20	200	.5	<.02
[1]110	<1	<.5	20	15	<200	.5	<.02
[1]125	<1	<.5	30	20	<200	<.5	.18
[1]137	<1	1	15	15	<200	<.5	.04
[2]138	<1	1	30	20	<200	<.5	<.02
[2]140	<1	5	30	20	<200	.1	<.02
[2]141	<1	1	15	10	<200	<.5	<.02
[2]152	40	25	100	500	1000	10.0	.06
153	5	1.5	30	30	<200	3.0	<0.02
164	5	2	100	20	<200	<0.5	<0.02
[2]165-A	1	4	100	50	<200	5	<0.02

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[1] Additional check samples collected; data not presented because values in all samples are below the minimums established for this table.

[2] Additional check samples collected—see table 3.

TABLE 2.—*Colorimetric, semiquantitative spectrographic, and atomic absorption analyses, in parts per million, of a selected group of stream-sediment samples from the Okanogan Range—Continued*

Sample	Colorimetric		Spectrographic (semiquantitative)				Atomic absorption
no.	xCu	cxHm	Cu	Pb	Zn	Ag	Au
165-B	5	5	30	50	<200	2	<0.02
166	30	14	50	100	200	10	<0.02
167	5	5	50	150	200	7	.04
168	10	7	50	100	<200	5	<.02
170	1	2	20	15	<200	<.5	.02
[2]207	<1	22	30	15	<200	<.5	<.02
[2]216	<1	1	20	15	<200	<.5	<.02
232	<1	1	30	15	<200	.5	<.04
234	<1	11	50	15	<200	<.5	<.04
236	20	2	100	15	<200	<.5	.02

Data from the spectrographic analyses were compared with the colorimetric chemical values for copper and heavy metals and examined for any other elements present in abnormally large amounts, especially silver. Additional samples were also collected from localities where the original sample contained ≥5 ppm Ag. A total of 91 supplementary samples was analyzed.

Later, it was discovered that values for xCu in the initial survey were unreliable, owing to copper contamination of chemicals used in the test, resulting in scattered spurious high values. Subsequently, all the samples from the initial survey, except for two for which the amount of sample was insufficient, were reanalyzed for xCu. Replicate cxHm analyses from a representative group of samples showed that these values were reproducible within acceptable limits of error. Acceptable reproducibility in xCu values was also found for a representative group of the supplementary suite of samples.

Results of the xCu and cxHm analyses, exclusive of all supplementary sampling, are plotted on plates 2 and 3 (in pocket). Approximate isopleths are drawn to show those localities where samples contain relatively high metal contents. A selected group of these analyses is shown in table 2 with accompanying atomic absorption values for gold (Au) and the semiquantitative spectrographic values for copper (Cu), lead (Pb), zinc (Zn), and silver (Ag). Sample numbers listed in the table are also shown on plate 1. A selected group of analyses of supplementary samples is shown in table 3. Table 2 and plate 1 also indicate localities where these samples were collected. To keep the tables short, the following minimum values, in parts per million, were used to select the analyses for both tables: xCu ≥5, cxHm ≥10, and all samples containing measurable Ag (≥0.5) and measurable Au (≥0.02). In table 3, if one of a group of supplementary samples meets or exceeds the minimum value, the entire group is listed. Because the early analytical results of the initial survey included the erroneously high xCu values, which partly governed selection of localities where supplementary samples were collected, it is not surprising that at only three localities are xCu values in the supplementary samples above the established minimum for inclusion in table 3.

TABLE 3.—*Colorimetric, semiquantitative spectrographic, and atomic absorption analyses, in parts per million, of a selected group of supplementary stream-sediment samples from the Okanogan Range*

[Sample localities only of original samples shown on plate 1. Colorimetric analysts, H. D. King and J. R. Hassemer; spectrographic analyst, G. Day and K. C. Watts; atomic absorption analysts, J. G. Frisken, R. Babcock, and R. D. Culbertson. Of 25 additional elements determined, none was judged to be present in anomalous amounts, and they are not shown here; n.d., not determined]

Sample no.		Colorimetric		Semiquantitative spectrographic				Atomic absorption	Location of original sample, and comments
Original	Check sample	xCu	cxHm	Cu	Pb	Zn	Ag	Au	
T-42-B	T-42-B1	1	3	20	20	<200	<0.5	<0.02	Sec. 29, T. 36 N., R. 24 E. Three samples each along two parallel dry gullies 100 ft apart; spaced equidistant above and below 42-B for total distance of 1,200 ft
	T-42-B2	3	1	10	10	<200	<0.5	<0.02	
	T-42-B3	4	6	20	15	<200	<0.5	<0.02	
	T-42-B4	10	1	30	20	<200	<0.5	<0.02	
	T-42-B5	4	4	30	15	<200	<0.5	<0.02	
	T-42-B6	10	4	50	10	<200	<0.5	<0.02	
T-43-B	T-43-B1	2	1	7	10	<200	<0.5	<0.02	Sec. 29, T. 36 N., R. 24 E. Westernmost of two adjacent streams; B-1, approximate original sample site; B-2, B-3, and B-4, progressively upstream from B-1 at intervals of 200, 200, and 50 ft, respectively
	T-43-B2	3	1	10	15	<200	<0.5	<0.02	
	T-43-B3	7	5	30	15	<200	<0.5	<0.02	
	T-43-B4	2	0.5	7	10	<200	<0.5	<0.02	
T-54	T-54-A	4	40	30	15	2000	1	<0.02	Sec. 11, T. 35 N., R. 24 E. 54-C, approximate original sample site; 54-A and 54-B, approximately 400 ft apart, from dry gully 1,500 ft north-northeast of original sample site
	T-54-B	2	10	20	30	500	1	<0.02	
	T-54-C	1	4	20	20	200	0.5	<0.02	
T-102	T-1021	4	6	20	50	<200	1	<0.02	Sec. 23, T. 35 N., R. 24 E. 1021, approximate original sample site; 1022 and 1023, 200-ft intervals up gully; dry
	T-1022	3	7	10	30	<200	<0.5	<0.02	
	T-1023	4	1	10	20	<200	0.5	<0.02	
T-138	T-1381	1	0.5	10	10	<200	<0.5	0.04	Sec. 6, T. 37 N., R. 25 E. 1381, approximate original sample site; 1382, 300 ft upstream; 1383, 450 ft upstream from 1382
	T-1382	1	0.5	7	20	<200	<0.5	<0.02	
	T-1383	1	2	10	10	<200	<0.5	<0.02	
T-140	T-1401	1	2	20	15	<200	2	<0.02	Sec. 2, T. 34 N., R. 24 E. 1401, approximate original sample site; 1402 and 1403, 100-ft intervals upstream; sluggish swampy stream
	T-1402	1	2	30	20	<200	1	<0.02	
	T-1403	1	0.5	30	15	<200	3	<0.02	

TABLE 3.—*Colorimetric, semiquantitative spectrographic, and atomic absorption analyses, in parts per million, of a selected group of supplementary stream-sediment samples from the Okanogan Range—Continued*

Sample no.		Colorimetric		Semiquantitative spectrographic				Atomic absorption	Location of original sample, and comments
Original	Check sample	xCu	cxHm	Cu	Pb	Zn	Ag	Au	
	T-1411	n.d.	2	7	20	<200	0.5	<0.02	Sec. 14, T. 34 N., R. 24 E. 1411, approximate original sample site; 1412 and 1413, 100-ft intervals upstream; sluggish, swampy stream
T-141	T-1412	<1	1	15	30	<200	<0.5	<0.02	
	T-1413	<1	2	10	30	<200	<0.5	<0.02	
	T-1521	30	>100	70	30	700	2	<0.02	Sec. 31, T. 35 N., R. 25 E. 1521, approximate original sample site; 1522 and 1523, 100 ft up- and down-gully, respectively, from original sample site; dry. Aerial photographs show probable mine dump not far up-gully from 1522
T-152	T-1522	240	>100	200	700	1000	20	0.02	
	T-1523	200	>100	100	500	500	5	<0.02	
	T-1651	<1	6	7	15	<200	<0.5	<0.02	Sec. 6, T. 34 N., R. 25 E. 1651, (sec. 31), swampy stream 2,500 ft north of original sample site; 1652 (sec. 6), 300 ft south 1651; 1653 (sec. 1), 3,500 ft south 47° west of original sample site; (in Loup Loup Creek)
T-165-A	T-1652	3	0.5	50	20	<200	1.5	<0.02	
	T-1653	<1	4	15	20	<200	0.5	<0.02	
	T-2071	<1	4	5	15	<200	<0.5	0.02	Sec. 26, T. 39 N., R. 23 E. 2071, approximate original sample site (nearly stagnant stream below beaver dam); 2072 and 2073, 400-ft interval below 2071 in swampy, ill-defined channel
T-207	T-2072	<1	3	<5	10	<200	<0.5	<0.02	
	T-2073	<1	5	7	20	<200	<0.5	<0.02	
	T-2161	<1	1	<5	10	<200	<0.5	<0.02	Sec. 9, T. 38 N., R. 23 E. 2161, approximate original sample site; 2162 and 2163, north and south branches, respectively, about 300 ft east of 216; 2164, 300 ft upstream from 2162; 2165, 300 ft upstream from 2163
	T-2162	<1	2	10	20	<200	<0.5	<0.02	
T-216	T-2163	<1	2	<5	15	<200	<0.5	.02	
	T-2164	<1	2	<5	10	<200	<0.5	<0.02	
	T-2165	<1	3	<5	10	<200	<0.5	<0.02	

The distribution of values within the sample space is shown by the histograms in figure 2. Both distributions are highly skewed and appear to be approximately lognormal. Copper (xCu) ranges from less than 1 to 40 ppm, and heavy-metal (cxHm) content ranges from less than 0.5 to 28 ppm. Geometric means are 0.15 ppm and 1.65 ppm, respectively. The geometric means were determined from cumulative frequency curves (fig. 3), plotted on lognormal probability paper, that were constructed as an aid in selecting threshold levels for anomalous values, generally in the manner suggested by Lepeltier (1969). Selection of these levels is highly subjective because of many variables in the sampling scheme that are impossible or impracticable to control. Following Lepeltier's method, however, values greater than approximately 10 ppm xCu and 10 ppm cxHm are considered anomalous. These values are the approximate points on the abscissa where the 2½ percent ordinate line (two standard deviations) intersects the distribution curves.

Histograms showing the distribution of spectrographically determined values for Cu and Pb for all samples are shown in figure 4. None is shown for Zn inasmuch as the sensitivity level for Zn is so high (about 200 ppm) that less than 10 percent of the samples showed measurable amounts.

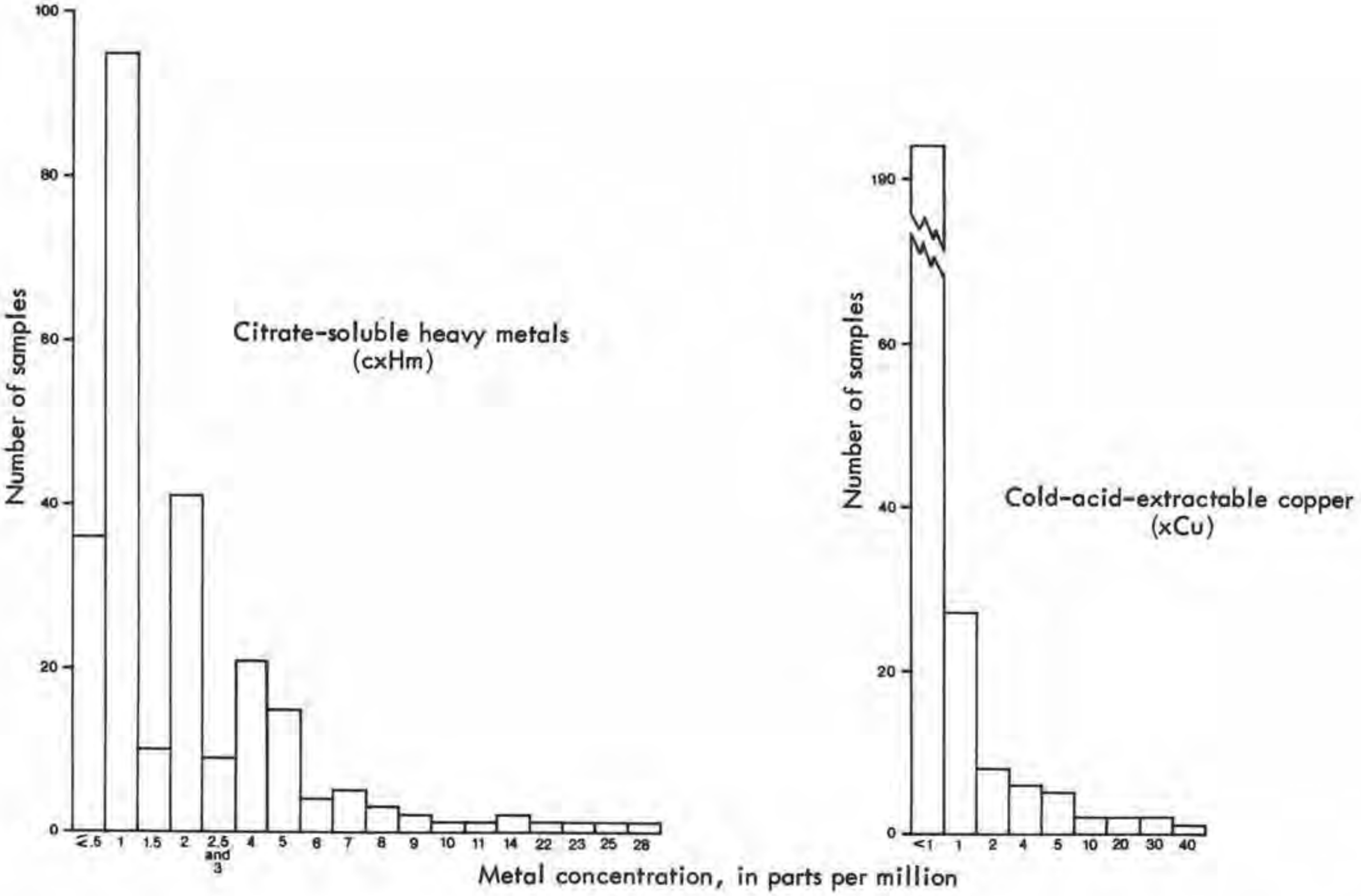

FIGURE 2.—Histograms showing distribution of values of citrate-soluble heavy metals (cxHm) and cold-acid-extractable copper (xCu).

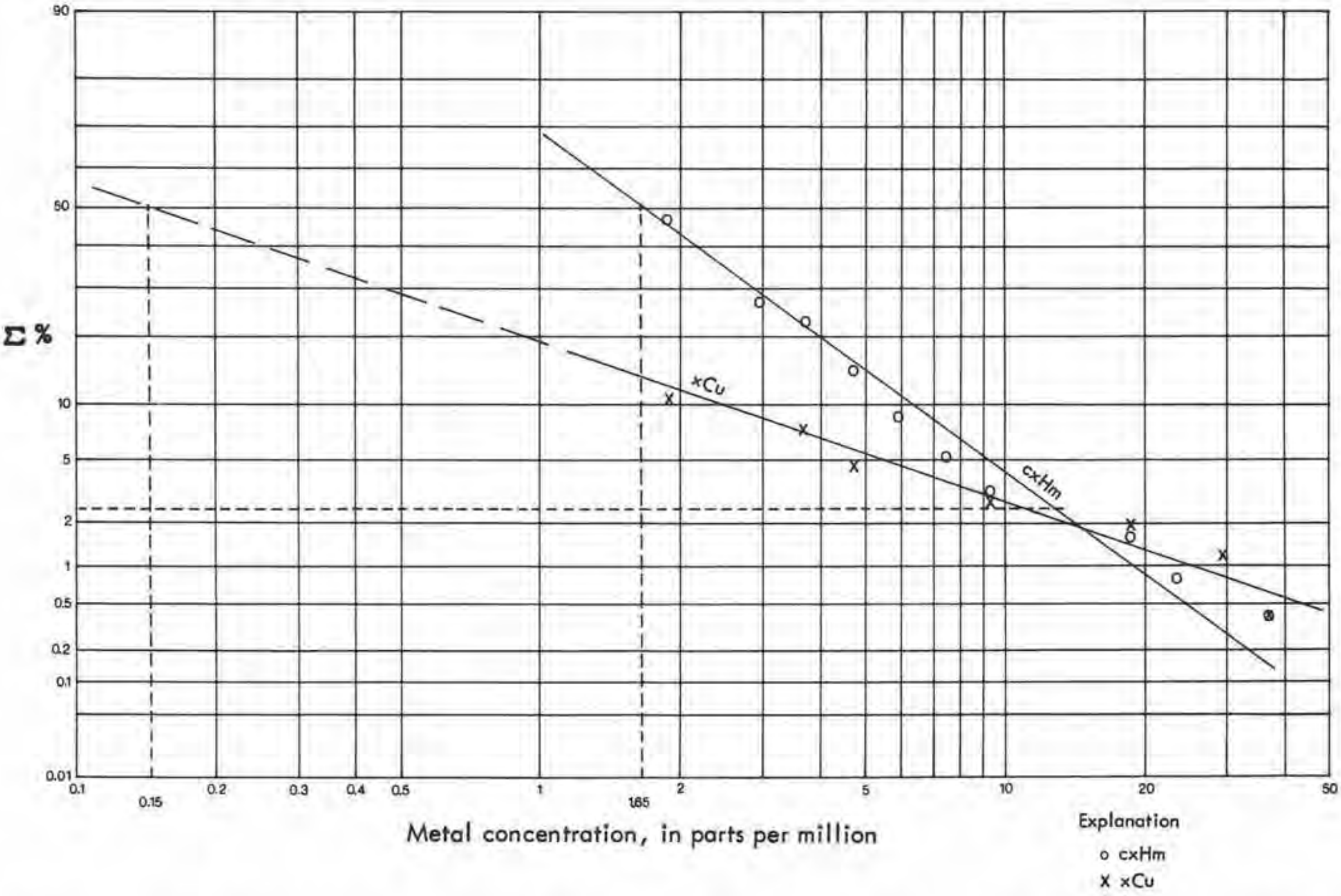

FIGURE 3.— Cumulative fequency distribution for citrate-soluble heavy metals (cxHm) and cold-acid-extractable copper (xCu). Dashed lines at 0.15 and 1.65 ppm are geometric means used in selecting threshold levels for anomalous values (Lepeltier, 1969). Dashed line at 2½ percent is two standard deviation.

Discussion.—When the isopleths (pls. 2, 3) are superimposed on the geologic map (pl. 1), it becomes readily apparent that most of the higher concentrations of xCu and cxHm, both anomalous and subanomalous, fall within drainages containing known mineralized ground, such as those flanking Ruby Hill and Mineral Hill, and along Salmon Creek, both north and south of Conconully. In these areas xCu and cxHm anomalies overlap strikingly, although they do not duplicate each other completely. (Although copper is also one of the group of metals included in the cxHm determination, its effect on that value is sufficiently small that copper alone would not ordinarily create a cxHm anomaly.) Elsewhere there is only minor overlap. Lack of overlap is especially conspicuous at the cxHm anomaly at the east end of Long Swamp (T-207), in the northern part of the map area, which is accompanied by only background levels of xCu. Except for a possible tendency to occur near plutonic contacts, only a few of the anomalies show a clear relation to the geology as depicted on plate 1. For example, the cxHm anomaly at Long Swamp is downstream from the contact between the Cathedral and Tillman Mountain plutons, yet a few miles southeast of the latter, another cxHm anomaly (T-234) lies near, but upstream from, the western contact of the small monzonite pluton. Another cxHm anomaly is

2 miles (3 km) south of Horseshoe Basin in the northern extremity of the drainage of the Middle Fork of Toats Coulee Creek. That information is from data supplied by M. H. Staatz (written communication, 1975), collected as part of a study of the Pasayten Wilderness area (Staatz and others, 1971); these localities were not visited by the writer during the present investigation. The anomaly bears no obvious relation to the geology shown on plate 1 other than having as its host the Horseshoe Mountain pluton.

Only two xCu anomalies are not clearly associated with known mineralized ground, one at locality T-236 in the Cecil Creek drainage between Tillman and Douglas Mountains at the east border of plate 1, and the other at T-49-B on the eastern slope of Muckamuck Mountain. Locality T-236, although down-canyon from a molybdenum-bearing prospect, noted earlier, is in a north-trending gully tributary to Cecil Creek. The area drained by this gully was not examined for evidence of prospecting, nor were

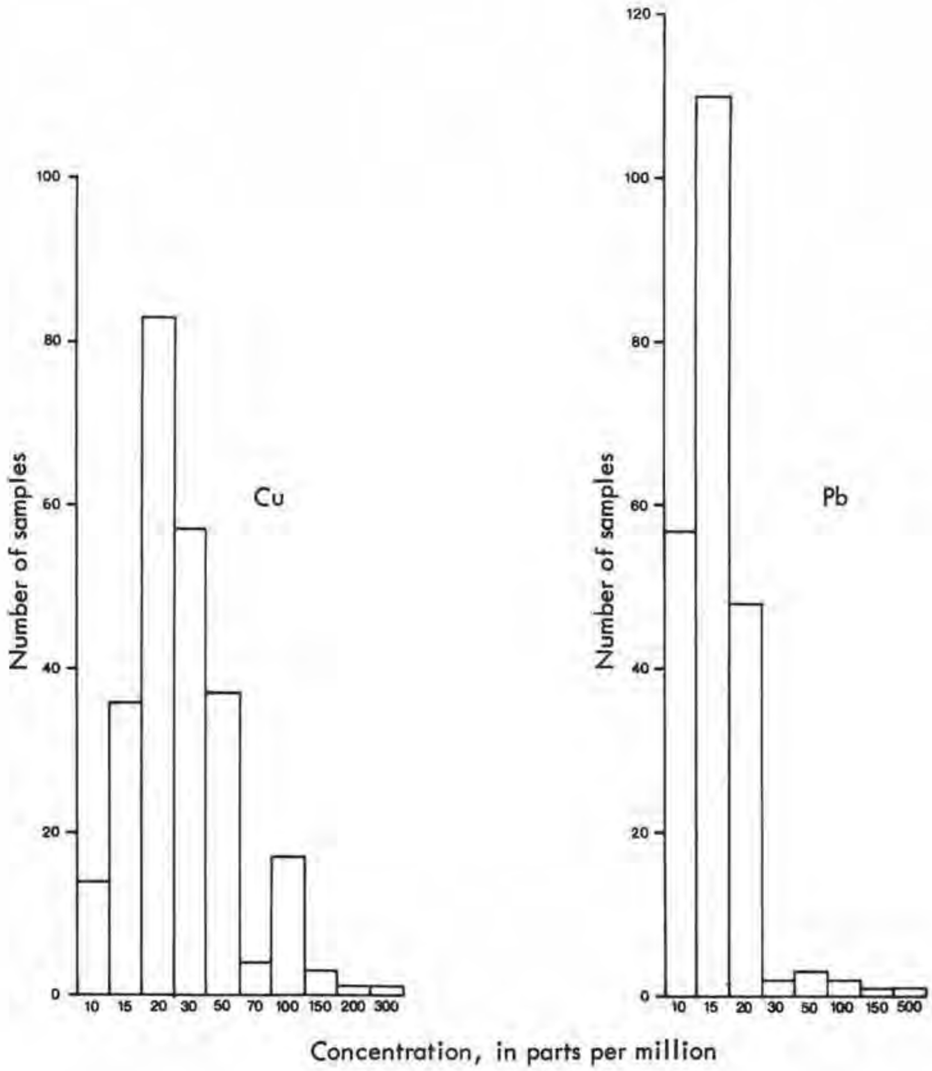

FIGURE 4.—Histograms showing distribution of spectrographically determined Cu and Pb.

supplementary samples collected there. Locality T-49-B is in the northernmost of two adjacent tributaries of Center Creek about 21 m apart where they are intersected by a logging road (not on the map). West of the sample locality this stream bends abruptly northwestward and drains the western side of a low unforested hill, named Sophys Meadows, and the eastern slope of Muckamuck Mountain. No evidence of prospecting was noted although a traverse nearby revealed exposures of olivine-bearing metagabbro at Sophys Meadows. This may account for anomalously high values for nickel (200 ppm) and vanadium (200 ppm) in this sample, as determined spectrographically, both of which are about four times greater than average values. The xCu anomaly on the north slope of the canyon of Sinlahekin Creek is simply repeated from published data to the east (Fox and Rinehart, 1972); no additional sampling there was done during the present investigation.

Although all samples in the initial suite containing measurable silver and gold are listed in the tables and indicated on plate 2, neither metal is considered sufficiently abundant to constitute an anomaly except for silver values at Ruby Hill. Those values are not surprising in view of the recorded silver production from mines at Ruby Hill. Elsewhere, silver values are generally only slightly above the limit of detectability, and most of these localities are within drainages influenced by known mineralized ground. A notable feature is the substantially greater downstream persistence of silver as compared with either xCu or cxHm. This is particularly well shown west of Ruby Hill and Peacock Mountain.

Gold values at T-1 and T-125 were the only ones sufficiently high to warrant collecting supplementary samples; analyses of the latter, however, failed to confirm the initial values. Locality T-125 is especially interesting because it occurs in Tertiary volcanic terrane, although farther west upper Sinlahekin Creek drains Mesozoic granitoid terrane.

CONCLUSIONS

The ability of both xCu and cxHm methods to detect mineral deposits like those in the present area of investigation is fairly well documented on plates 2 and 3, and, in places, spectrographically determined silver values also are obviously useful. Recommendations for further geochemical exploration include the obvious suggestion to carry out somewhat more detailed sampling in areas of anomalous and subanomalous highs in order to identify mineralized source terrane. In addition, it might be profitable to utilize other more sensitive analytical techniques such as atomic absorption in testing for silver in the light of its superior downstream persistence, at least locally, over both xCu and cxHm.

In summary, it should be pointed out that although anomalies comparable to those at known deposits were not found, the sampling survey was reconnaissance in nature and sample density less than optimum. Hence, the area should by no means be considered devoid of promise on the basis of the results of this investigation.

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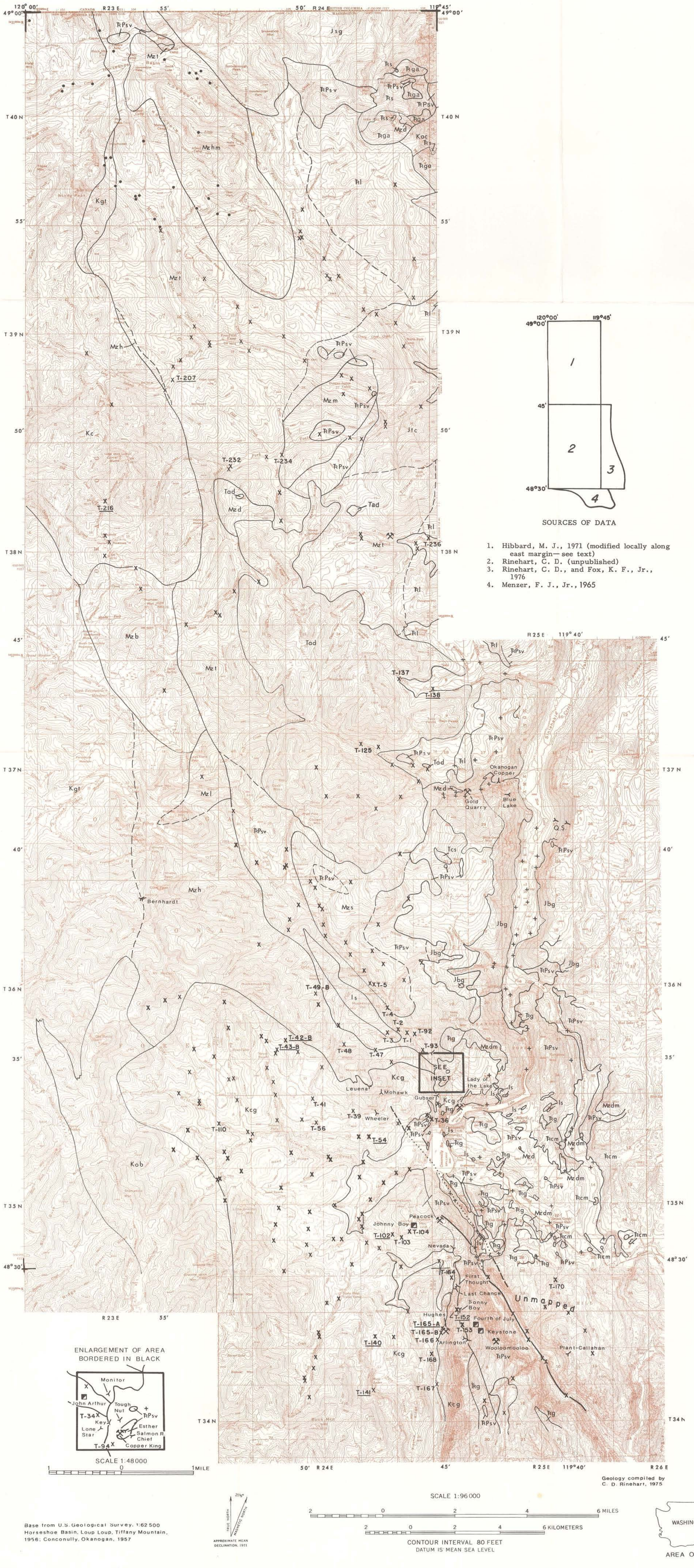
WASHINGTON DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND EARTH RESOURCES

PREPARED IN COOPERATION WITH THE
U.S. GEOLOGICAL SURVEY

BULLETIN 74
PLATE 1



SOURCES OF DATA

1. Hibbard, M. J., 1971 (modified locally along east margin—see text)
2. Rinehart, C. D. (unpublished)
3. Rinehart, C. D., and Fox, K. F., Jr., 1976
4. Menzer, F. J., Jr., 1965

Geology compiled by
C. D. Rinehart, 1975

Base from U.S. Geological Survey, 1:62500
Horseshoe Basin, Loup Loup, Tiffany Mountain,
1956; Conconully, Okanogan, 1957

TRUE NORTH
MAGNETIC NORTH
21½°
APPROXIMATE MEAN
DECLINATION, 1971

SCALE 1:96000
2 0 2 4 6 MILES
2 0 2 4 6 KILOMETERS
CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

AREA OF MAP

GEOLOGIC MAP OF PART OF THE OKANOGAN RANGE, WASHINGTON

EXPLANATION

QUATERNARY

Pleistocene and Holocene

Surficial deposits

Includes alluvium, colluvium, talus, and glacial drift

TERTIARY

Eocene

VOLCANIC AND EPICLASTIC SEDIMENTARY ROCKS

Tad

Andesite and dacite

Lava flows, flow breccias, and pyroclastic rocks

Tcs

Conglomerate and sandstone

One small outcrop at Bald Butte (sec. 31, T. 37 N., R. 25 E.), west of Sinlahekin Game Range

MESOZOIC

MESOZONAL IGNEOUS ROCKS

Plutonic rocks

Plutonic units described below and identified by letter symbol that also indicates geologic age—(T̵R) Triassic, (J) Jurassic, (K) Cretaceous, or (Mz) Mesozoic undivided. Relative ages unknown except as noted. Plutons listed in general north-to-south order

Jsg, *Similkameen composite pluton; granodiorite; subporphyritic, medium-grained*

Mzhm, *Horseshoe Mountain pluton; quartz monzonite; porphyritic, coarse-grained*

Kc, *Cathedral pluton; quartz monzonite; coarse-grained*

Mzt, *Tillman Mountain pluton; tonalite (quartz diorite); fine- to medium-grained; intruded(?) by units* Kgt, Mzhm, *and* Mzd *in northern part of map area (Hibbard, 1971, table 1)*

Kac, *Anderson Creek pluton; granodioritic; fine- to medium-grained*

Mzd, *diorite, quartz diorite, and gabbro; fine- to medium-grained; generally in small stocks and dikelike masses; largest stock is quartz diorite in the north-central part of map area. Also includes one small body of medium- to coarse-grained gabbro on Chopaka Mountain, and small bodies of diorite in southern part of map area*

Mzh, *hybrid granitoid rocks; fine- to coarse-grained, wide range in composition and texture, but typically gneissic and granodiorite in average composition. Northernmost lentil believed by Hibbard to have resulted from* Mzm *and* Kgt *magmas syntectonically intruded into unit* Mzt

Jtc, *Toats Coulee pluton (North Fork Camp hybrid gneiss of Hibbard, 1971; also includes 1 km^2 of Hibbard's Bowers quartz diorite); largely hybrid granitoid rocks showing striking wide range in composition, texture, and structure, but typically gneissic, medium-grained, and probably granodiorite in average composition. Hibbard believes this unit represents intrusion of* Mzm *and* Kgt *magmas into cataclastic zones in the older Tillman Mountain pluton*

Mzm, *monzonite pluton; medium- to coarse-grained*

T̵Rl, *Loomis pluton; granodiorite and quartz diorite; medium-grained; intruded by units* Kac *and* Mzd *in northeastern part of map area*

Mzb, *Bottle Spring pluton; quartz monzonite and granodiorite; medium-grained*

Mzl, *Lone Frank pluton; quartz diorite; medium-grained; intruded by Bottle Spring pluton*

Jbg, *Blue Goat pluton; granodiorite, medium-grained, subporphyritic*

Mzs, *granodioritic gneiss of Salmon Meadows; mostly gneissic but locally massive, medium-grained; some gneiss may be paragneiss; may be correlative with Tillman Mountain pluton*

Kgt, *gneissic trondhjemite of Tiffany Mountain; medium-grained, locally massive; dark minerals commonly distributed as irregular, locally swirled schlieren; intruded by Old Baldy pluton*

Kcg, *Conconully pluton; granodiorite; medium-grained*

Kob, *Old Baldy pluton; medium-grained, locally gneissose; intruded by Conconully pluton*

Mzdm, *Dunn Mountain pluton; granodiorite; fine- to medium-grained*

METAMORPHIC ROCKS

TRIASSIC

T̵Rs T̵Rga

Metamorphosed mafic and ultramafic rocks

Occur at Chopaka Mountain in northeast corner of map
T̵Rs, *serpentinite*
T̵Rga, *metagabbro*

T̵Rg

Metagranitoid rocks

Mostly metagranodiorite, but includes some metaquartz diorite; for convenience, also includes one small metamorphosed felsic mass south of Fish Lake

T̵Rcm

Cave Mountain Formation

Mostly metalimestone and metadolomite with subordinate slate, metasiltstone, and metavolcanic rocks; occurs in southeastern part of map only

PERMIAN AND TRIASSIC

T̵RPsv ls

Metasedimentary and metavolcanic rocks

Metachert, quartzite, quartzofeldspathic schist, mica schist, calc-silicate schist, amphibolite

ls, *chiefly metalimestone, lesser metadolomite, and calc-silicate hornfels*

Contact

Dashed where gradational

Fault, showing dip

Dashed where approximately located, dotted where concealed.

◩ Shaft
Adit
⚒ Unspecified

Mine or prospect

Name shown where known

x T-54	+	•
This survey	Previous survey (Fox and Rinehart, 1972)	Pasayten Wilderness survey (Staatz and others, 1971, and Staatz, written communication, 1974)

Geochemical sample locality

Number indicates additional analytical data given in table 2; underlined number indicates analytical data, from supplementary sampling, given in table 3

WASHINGTON DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND EARTH RESOURCES

PREPARED IN COOPERATION WITH THE
U.S. GEOLOGICAL SURVEY

BULLETIN 74
PLATE 2

EXPLANATION

3½

Contour showing concentration of cold-acid-extractable copper (xCu)

Hachures toward direction of declining values. Contours at 3½, 6½, 9½, and 15½ parts per million

7

Measured concentration of cold-acid-extractable copper (xCu), in parts per million

(.5)

Silver, where measurable, in parts per million

[.04]

Gold, where measurable, in parts per million

COLD-ACID-EXTRACTABLE COPPER (xCu) IN GULLY AND STREAM SEDIMENTS

Overlay to geologic map (Plate 1)

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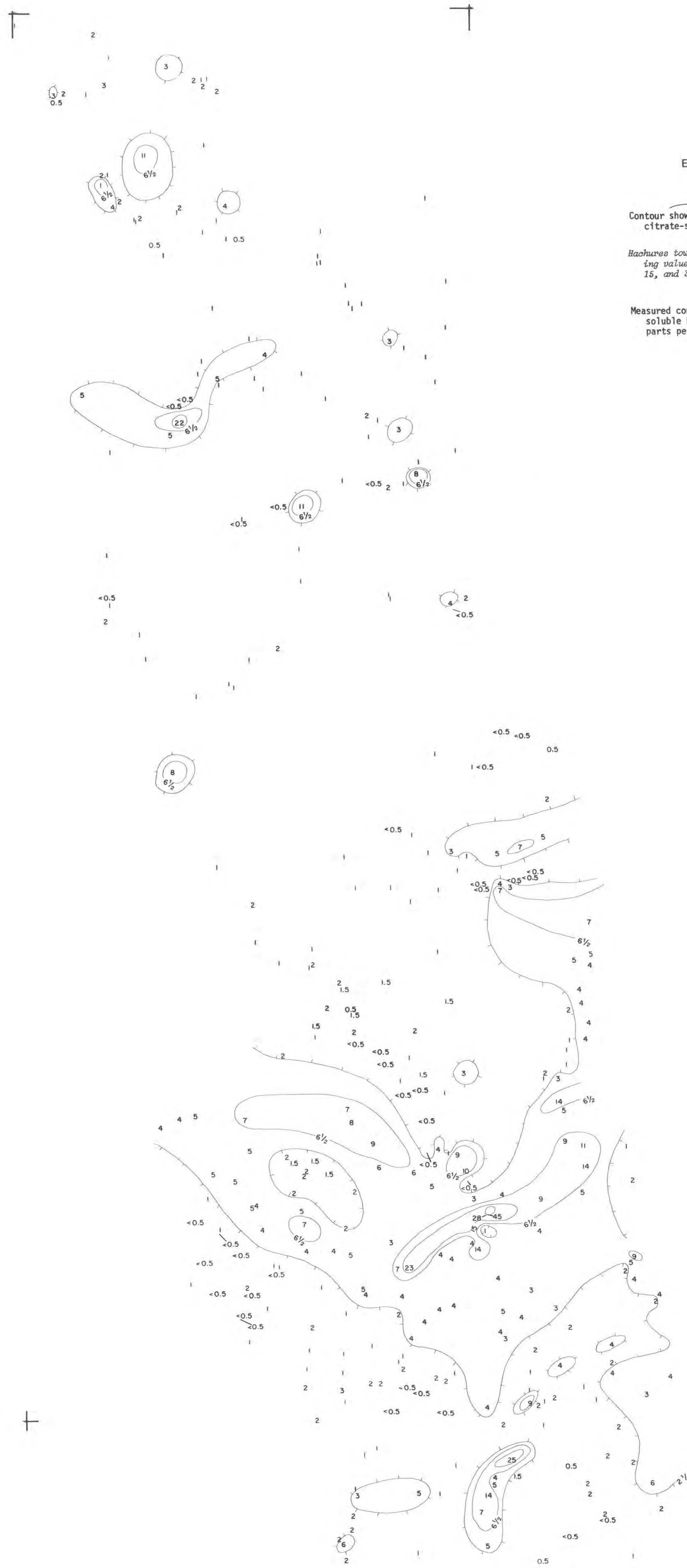

EXPLANATION

2½

Contour showing concentration of citrate-soluble heavy metals (cxHm)

Hachures toward direction of declining values. Contours at 2½, 6½, 15, and 30 parts per million

6

Measured concentration of citrate-soluble heavy metals (cxHm), in parts per million

SCALE 1:96 000

2 0 2 4 6 MILES

2 0 2 4 6 KILOMETERS

CITRATE-SOLUBLE HEAVY METALS (cxHm) IN GULLY AND STREAM SEDIMENTS

Overlay to geologic map (Plate 1)