U. S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Geochemical data and sample locality maps for stream-sediment, heavy-mineral-concentrate, mill tailing, water, and precipitate samples collected in and around the Holden mine, Chelan County, Washington

By

J.E. Kilburn[*], G.C. Whitney[**], W.M. d'Angelo[*], D.L. Fey[*],
R.T. Hopkins[*], A.L. Meier[*], J.M. Motooka[*],
B.H. Roushey[*], and S.J. Sutley[*]

Open File Report 94-680A Paper version
94-680B Diskette version

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

[*] U.S. Geological Survey, DFC, Box 25046, MS 973, Denver, CO 80225
[**] U.S. Geological Survey, DFC, Box 25046, MS 904, Denver, CO 80225

1994

CONTENTS

Page

ILLUSTRATIONS

TABLES

CONTENTS (continued)

INTRODUCTION

A geochemical reconnaissance survey was conducted in the summer of 1994 in and around the Holden mine in north-central Washington as part of an integrated mineral-resource and mineral-environmental assessment of Wenatchee National Forest. The purpose of this study was to evaluate possible environmental hazards associated with the abandoned mine complex, a former producer of copper, zinc, silver, and gold ore. The Holden mine site in 1994 consists largely of mill tailings, waste dumps, portal and shafts, dismantled mill, and other surface structures. Sample media included stream sediments, heavy-mineral concentrates, mill tailings, waters, and effluent related salts and precipitates. This report presents the analytical results (tables 1-7) and sample locality maps (figs. 2-5) for the Holden study.

The Holden mine is located on Railroad Creek, some 12 miles west of Lake Chelan, Chelan County, Washington (fig. 1). Because of its remote locale, access is limited to regularly scheduled boat service out of Chelan or by floatplane to Lucerne, a former resort community that is now a Forest Service ranger station and campground. From Lucerne you may drive on a graded dirt road or hike the remaining 12 miles to Holden. Topographic relief is great in the Holden area, rising from 1100 ft at Lake Chelan to over 9500 ft at Bonanza Peak, with many of the neighboring peaks rising to elevations over 8000 ft. The region displays evidence of prolonged and extensive glaciation. Railroad Creek drains a generally straight, steep-sided U-shaped valley marked by hanging valleys and glacial lakes. In some of the higher basins small glaciers persist. The valley floor is covered with a deep glacial overburden that is largely hidden by thick underbrush and scattered stands of timber.

Geologic Setting

The Holden mine lies within the crystalline core of the northern Cascade Range, a region characterized by three major northwest-trending tectonostratigraphic units: the Nason, the Swakane, and the Chelan Mountains terranes. The Holden ore body is located in the Chelan Block of the Chelan Mountains terrane (Dragovitch and Derkey, 1994). The most detailed account of the Holden area geology and a correlation of the rock units is given in Cater and Crowder (1967). The oldest rocks exposed in the Holden area, the Swakane Biotite Gneiss, are considered early Paleozoic or older based on zircon age dating. This unit consists primarily of biotite gneiss interbedded locally with horneblende schist and gneiss, clinozoisite-epidote gneiss, and quartzite (Cater, 1982). Overlying the Swakane Biotite Gneiss is a complex succession of upper Paleozoic metamorphic rocks referred to as "younger gneissic rocks of the Holden area" by Cater and Crowder (1967). This highly folded sequence includes schists and gneisses of varying compositions interbedded with quartzite and marble lenses. Unconformably overlying the older gneiss and schist units are shale, arkosic sandstone, and conglomerate of the Swauk

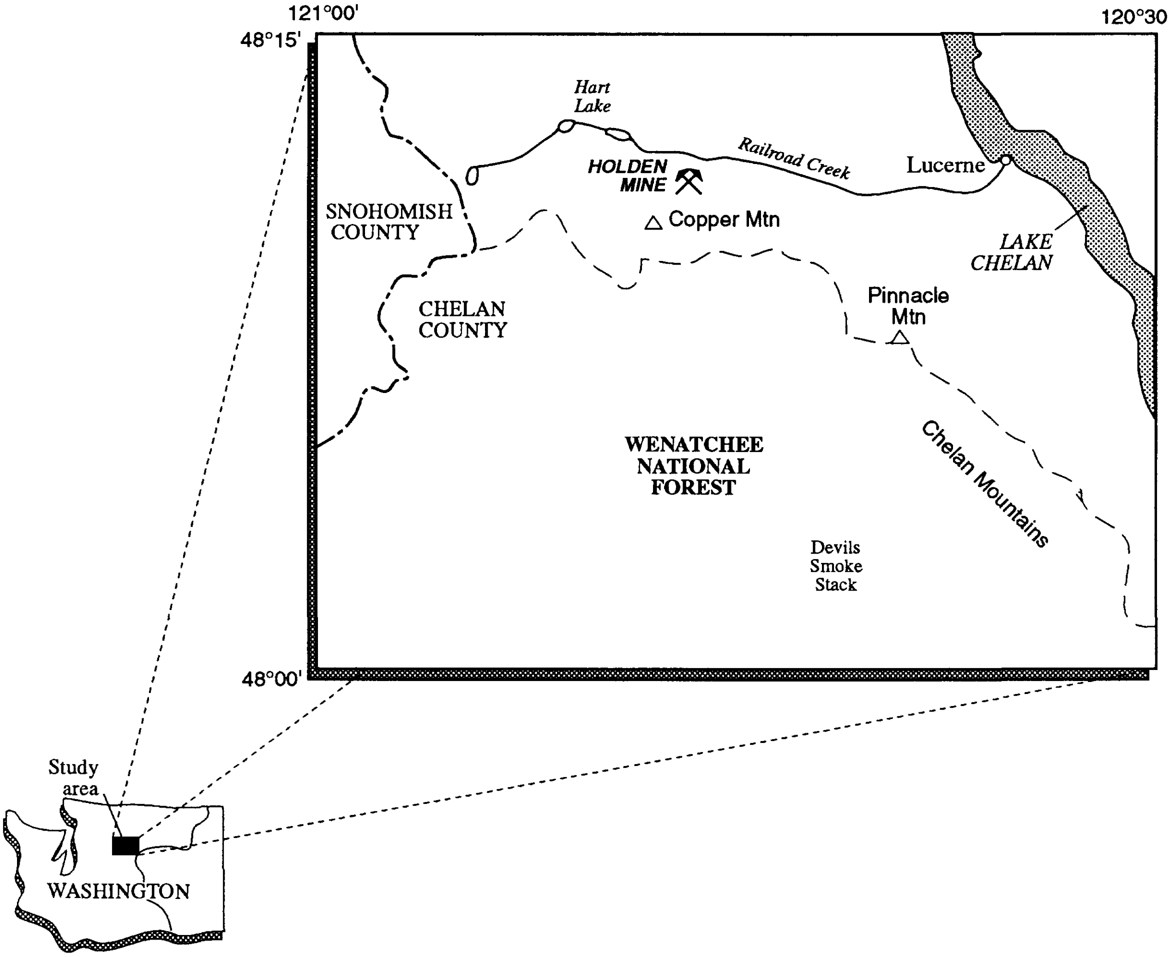


Figure 1. Location of the Holden Mine, Chelan County, Washington

Formation, the youngest supracrustal rocks mapped in the area (Crater, 1982). These rocks, formerly considered to be of Paleocene age (Crater and Crowder, 1967), are more likely Eocene based on interpretation of recent data (Crater, 1982).

Igneous rocks in the north Cascade Range vary considerably in age and composition. Pre-Tertiary ultramafic rocks of uncertain age mainly occur as small masses consisting of gabbro, hornblendite, and peridotite that are locally altered to serpentine. In addition, ultramafic rocks of probable Eocene age outcrop on the surface and underground workings of the Holden mine. These younger ultramafic rocks consist of larger masses of hornblendite and hornblende peridotite and hornblende gabbro. (Cater,1982). Regionally, the most common igneous rocks are Mesozoic metamorphosed granitic intrusives (orthogneisses) (Nold, 1983), including the Triassic Dumbell Mountain plutons, the oldest granitoid rocks in the region with a radiometric date of roughly 220 m.y. The Dumbell Mountain plutons form a tight belt of northwest-trending rocks of gneissic hornblende-quartz diorite and quartz diorite gneiss (Cater,1982). Tertiary intrusions, ranging in age from early Eocene to Miocene, are also common to the region. These Tertiary intrusives are largely granodiorite in composition, but can range from gabbro to quartz monzonite in a single mass (Cater, 1982).

Mining History

In the summer of 1887, a location engineer in search of a viable route for the Great Northern Railroad, was the first to report and describe the weathered, rust-colored gossan earmarking the eventual site of the Holden mine. Accounts of these altered rocks soon spread, and claims were staked in the area by July 1892. Over the next 36 years, a number of individuals and syndicates held options on the Holden site, although efforts to develop the claims were unsuccessful (Youngberg and Wilson, 1952; McWilliams, 1958). In 1928, the Britannia Mining and Smelting Co., a subsidiary of the Howe Sound Co., acquired the property (Youngberg and Wilson, 1952). Authority to carefully assess the deposit and conduct further exploration was awarded to another designated subsidiary, the Chelan Copper Mining Co. In 1937, the subsidiary relationship was dissolved, and the Howe Sound Co. took over the operation and development of the property. The Holden deposit shortly became the producing Holden mine in April 1938. The mine was active for 19 years, discontinuing operations in June 1957 because of high production costs and a drop in the copper market. While operative, over 212 million pounds of copper, 40 million pounds of zinc, 2 million ounces of silver, and 600 thousand ounces of gold were extracted from 10 million tons of ore (McWilliams, 1958).

Local Geology and Mineralization at the Holden Mine

The Holden mine is a relatively low grade copper-zinc-silver-gold volcanogenic massive sulfide (VMS) deposit that is strata-bound within a sequence of steeply dipping, high-grade metamorphic rocks, largely consisting of calc-silicate gneisses and amphibolites. These rocks are more or less andesitic in chemical makeup, suggesting andesitic volcanics and related volcaniclastic sedimentary rocks as likely protoliths. The orebody is hosted in a pyritic sericite-quartz schist sequence within the high-grade metamorphic rocks. Exposures of the ore-bearing schist, which ranges from 300 to 600 ft in thickness, can be traced for at least three miles on the surface (Nold, 1983). The deposit is stratiform within the schist unit and displays the well developed metal zoning (Nold, 1983) characteristic of VMS deposits, with a lower or original copper-rich footwall and a zinc-rich upper or original hanging wall (Guilbert and Park, 1986). This primary metal zoning has endured the ravages of high-grade metamorphism as well as intense deformation, which has overturned the deposit, resulting in a copper-rich zone structurally above the zinc-rich zone (Nold, 1983). The most important ore and ore-related minerals include pyrite, pyrrhotite, chalcopyrite, sphalerite, and native gold. Galena, magnetite, and molybdenite are also present but are merely considered accessory. The gold is mainly related to chalcopyrite in the structural hanging wall, while silver is associated with sphalerite in the structural footwall (McWilliams, 1958). Mineralization is for the most part disseminated, although massive ores are found locally in the zinc-rich zone (Nold, 1983).

METHODS OF STUDY

Sample Media

The intent of this reconnaissance study was to rapidly identify, at a relatively low cost, the possible contaminating effects of waters draining sulfide-rich mill tailings at the Holden mine. Sample media for this environmental survey included stream-sediment, heavy-mineral-concentrate, mill tailings, effluent related salts or precipitates, and water samples. Sediment (including concentrates) and water sampling was carried out at and downstream from the Holden mine and from streams or creeks draining altered and mineralized areas, which have been impacted little if any by mining activity. Comparing sediment and concentrate data (trace element signatures) from the mine with corresponding samples from the undeveloped mineralized areas should allow us to determine if the mineralization is similar in nature. If so, then the water chemistry of these sampled areas should, by comparison, provide some insight regarding the natural geochemical background levels of water associated with undeveloped mineralized areas as opposed to water draining the highly disturbed terrain of a similarly mineralized but fully developed mine. The following paragraphs briefly describe each sample medium.

Stream-sediments provide a geochemical composite of the transported components of an entire drainage basin. Their chemical composition is controlled predominantly by the major geologic units of the drainage basin and to a lesser extent by scavenging materials such as amorphous iron-manganese oxides, clays, and organic matter. Minor constituents within the sediment load, such as elements associated with potentially economic mineral deposits, may be detected in the sediment analysis, but the influence is often small because of dilution by the large bulk of barren transported material. For this reason, a derivative sample, the heavy-mineral-concentrate, is gathered in combination with the stream sediment. The purpose of this medium is the preferential concentration of the transported heavy-mineral portion of a stream or drainage basin (which may include minerals that result from ore-forming processes). With most of the rock-forming silicates, clays, and organic material removed, concentrations of ore-related elements may be reciprocally enhanced to the point that chances of recognizing geochemical anomalies are greatly improved.

Mill tailings, which can be major sources for acid waters and metals in the environment, were collected at the Holden mine in order to determine their chemical properties and heavy-metal content. In addition, various soluble salts and precipitates derived from sulfide weathering and related acid-generation were collected at the base of the mill tailings. These encrustations and precipitates often host exceedingly high concentrations of metals and acid-forming salts, which during periods of rain or seasonal snowmelt, readily dissolve, releasing their toxic constituents to the environment.

Water samples were collected in order to determine chemical characteristics such as pH, conductivity, and dissolved metal content. Most mineral deposits are inherently rich in sulfide minerals and sulfide rich rocks of non-economic significance are common in nature. Both represent possible sources of acid and metal loading in the environment. When oxygen-rich waters come in contact with solid waste material from mines such as dumps or mill tailings or drain naturally-occurring sulfide rich rocks, they often acquire high concentrations of acid and potentially toxic elements such as zinc, copper, cadmium, and arsenic. This noxious combination of acid waters and potentially toxic metals can adversely affect water quality, aquatic life, wildlife, and agriculture. Water sampling in the Holden area should provide in some measure, data reflecting the effects of mining on the environment as well as the water quality associated with undeveloped mineralized areas.

Sample Collection, Preparation, and Analysis

Stream Sediment

A total of 14 stream-sediment samples were collected from drainages in the Holden area. Each stream-sediment sample consisted of alluvium from the active stream or creek channel, composited by collecting sediment from several localities along a 10 m stretch of the channel. The sediment was sieved at the site through a minus-10 mesh (2 mm) stainless steel screen to remove coarse material. The samples were later air-dried, sieved to minus-80 mesh (0.177 mm) and pulverized to a fine flour consistency prior to analysis. The stream sediment samples were analyzed for 40 elements by the inductively coupled plasma-atomic emission spectrometry (ICP-AES) method of Briggs (1990). In order to determine lower concentrations of specific elements (Ag, As, Au, Bi, Cd, Cu, Mo, Pb, Sb, and Zn), the sediment samples were also analyzed by the ICP-AES technique of Motooka (1990), and for low-level gold by the graphite furnace atomic absorption spectrophotometry (AA) method of O'Leary and Meier (1990).

Heavy-Mineral Concentrates

A total of 14 heavy-mineral concentrate samples were collected. Each sample was gathered at a corresponding stream-sediment site. A bulk sample of active alluvium was collected and sieved through a minus-10 mesh (2 mm) stainless steel screen to remove coarse material. Care was taken to collect the samples from around boulders, rocks, and sandbars (the areas where heavy-minerals tend to congregate as a result of stream dynamics) to maximize the amount of heavy-mineral concentrate in the sample. This sieved sample was panned at the site until most of the less-dense minerals (primarily quartz and feldspar), organic materials, and clays were removed. This rough concentrate was placed in a bag, air-dried, and saved for further laboratory processing. In the laboratory, the panned concentrates were sieved to minus-35 mesh (0.50 mm) and gravity separated using bromoform (specific gravity 2.85) to remove remaining light minerals, again mostly quartz and feldspar. The heavy-mineral sample was then separated into magnetic, weakly magnetic, and nonmagnetic fractions using a modified Frantz Isodynamic Separator. The magnetic fraction was removed at a setting of 0.25 ampere and normally consists of magnetite and ilmenite. The weakly magnetic fraction was extracted at a setting of 1.75 ampere and mostly contains ferromagnesian silicates and iron oxides. The remaining nonmagnetic fraction may include ore and ore-related minerals, native metals such as gold, as well as accessory oxides and silicates. The nonmagnetic fraction was split using a Jones splitter. One split was hand ground with an agate mortar and pestle and analyzed by a direct-current arc, semiquantitative atomic emission spectrographic (DC-Arc AES) method (Adrian and others, 1990) and the other split saved for mineralogical studies.

Mill Tailings

A solitary grab sample of mill tailings was taken at the Holden mine. Processing the tailings for chemical analysis consisted of simply pulverizing a representative portion of the sample (the tailings were of extremely fine texture and no sieving was necessary). The tailing sample was analyzed for 40 elements by the ICP-AES method of Briggs (1990). In order to determine lower concentrations of certain elements (Ag, As, Au, Bi, Cd, Cu, Mo, Pb, Sb, and Zn), the sample was also analyzed by the ICP-AES method of Motooka (1990), and for gold by the graphite furnace AA method of O'Leary and Meier (1990).

Effluent Related Salts and Precipitates

Three types of precipitates were collected at the Holden site. These include: (1) a thick, flocculent, milky-white precipitate formed in waters that drain the main adit of the Holden mine; (2) salts that have precipitated and formed a thin crusty veneer at the base of the mill tailings; and (3) a mixture of highly oxidized tailings and precipitates that are associated with acidic waters or seepage at the foot of the mill tailings. A single sample of the milky-white precipitate was collected by simply spooning (plastic spoon) the substance into a 250 ml polypropylene bottle. The bottle was rinsed on site with a small amount of adit water prior to sampling. Five salt samples were scraped from the base of the tailings with a plastic knife and stored in plastic zip-lock bags. Three samples of the highly oxidized material was collected with a rock hammer and also stored in plastic zip-lock bags. Processing the precipitate samples involved simply grinding the sample to a fine powder with an agate mortar and pestle. Prior to this, however, the milky-white adit sample was filtered through coarse filter paper (25 microns), and the filtrate residue was saved for analysis. All the samples were analyzed for 40 elements by the ICP-AES method of Briggs (1990) and for 10 elements by the ICP-AES method of Motooka (1990). In addition, conventional x-ray powder diffraction techniques (Klug and Alexander, 1974) were employed to determine the mineralogy of the precipitate samples.

Waters

Water samples (17 individual sites) were collected from active streams and creeks in an around the Holden mine and along Railroad Creek. In addition, effluent seepage emerging from the base of the Holden mill tailings were also sampled. Two separate samples were gathered at each site including a 250 ml raw water sample taken for anion analysis and a 60 ml filtered sample acidified with nitric acid for cation analysis. Filtered samples were acidified to prevent precipitation of metals and bacterial growth. Disposable 0.45 micron filters were used for the collection of the filtered water samples. All water samples were collected in polypropylene bottles that were rinsed on site with a small amount of stream or seepage water for the raw water samples and filtered water for the filtered water samples. Anion content of the raw water samples were determined by the ion chromatography procedure of Fishman and Pyen (1979) and the cation component of the filtered and acidified samples by an unpublished inductively coupled plasma mass spectrometry (ICP-MS) method (A.L. Meier, written commun., 1994). In addition to temperature, on-site field measurements at each water sample site included tests for pH and conductivity using small pocket sized testers developed by OAKTON.

ANALYTICAL TECHNIQUES

Semiquantitative Emission Spectrography

The nonmagnetic heavy-mineral-concentrate samples were analyzed by a direct-current arc atomic emission spectrographic (DC-Arc AES) method (Adrian and others, 1990) for 37 major, minor, and trace elements. The procedure involves mixing 5 mg of sample with 25 mg of a 4:1 graphite-quartz mixture and packing the compound tightly into the cavity of a graphite electrode. The sample is then burned to completion in a direct-current arc at 12-15 amperes. The spectrum of the samples is recorded on photographic film and concentrations of the elements are determined by comparison with spectra obtained from laboratory reference standards. Standard concentrations are geometrically spaced over any given order of magnitude as follows: 100, 50, 20, 10, 5, 2, etc. Samples whose concentrations were estimated to fall between those values were assigned values of 70, 30, 15, 7, 3, 1.5, etc. The precision of this analytical technique is approximately ± one reporting interval at the 83 percent confidence level and ± two reporting intervals at the 96 percent confidence level (Motooka and Grimes, 1976). Elemental upper and lower limits of determination for this semiquantitative spectrographic method are given in table 8.

Ion Chromatography

The anions F, Cl, SO_4, NO_3, PO_4, and Br were determined simultaneously by ion chromatography on unfiltered and unacidified water (raw) samples following the procedure developed by Fishman and Pyen (1979). The water samples were injected into a chromatograph where ions of interest elute through an anion-ion exchange separator column at different rates depending on the affinity of each species for the ion-exchange resin. The sample then passes into a suppressor column and into a flow-through conductivity cell where the anions are detected and peak heights are recorded on an output chart. Unknown samples are compared with peak heights of reference standards to determine sample concentrations. Lower reporting limits are <0.05 ppm F, <0.1 ppm Cl, <1 ppm $S0_4$, <0.1 ppm NO_3, <1 ppm PO_4, and <0.1 ppm for Br.

Inductively Coupled Plasma Mass Spectrometry

Filtered and acidified water samples were analyzed for 62 elements by an unpublished inductively coupled plasma mass spectrometry (ICP-MS) technique (A.L. Meier, written commun., 1994). ICP-MS is an extremely useful analytical method because of its ability to rapidly determine over 60 elements directly in the water sample without the need for preconcentration or dilution and with detection limits in the sub-part-per-billion range and a linear range of six orders of magnitude or more. Calibration for this extensive elemental coverage is accomplished by constructing a response curve of the observed intensity for easily-ionized elements verses mass using a second order equation for a best fit over the entire mass range. The ion temperature and electron number density of the plasma are estimated using the data from the harder-to-ionize elements. These are used in the Saha equation to estimate the degree of ionization for all the elements in the plasma. By using the response curve derived, the degree of ionization, and the natural isotopic abundance, semi-quantitative estimates of concentration for all elements can be made in samples without the need of a calibration standard for every element. At this time, standardized analytical limits of determination have not been established for the ICP-MS procedure.

Graphite Furnace Atomic Absorption Spectrophotometry

Stream-sediment and mill tailing samples were analyzed for gold by the graphite furnace atomic absorption spectrophotometry (GF-AAS) method of O'Leary and Meier (1990). A 10-gram sample was ignited in a muffle furnace at 700°C for 1 hour, or until the sulfides and organic matter were completely oxidized. The cooled sample was digested on a hot plate with 10 mL HBr containing 0.5 percent Br_2. Ten mL methyl isobutyl ketone (MIBK) and 10 mL water were added to the cooled sample-acid mixture, which was then shaken for 3 minutes on a horizontal shaking machine and then centrifuged to separate the organic phase. The MIBK was washed with 40 mL 0.1 M HBr and the sample introduced into the graphite furnace of an atomic absorption spectrophotometer for gold determination. The lower and upper limits of determination are 0.002 ppm and 0.05 ppm Au, respectively. Concentrations above 0.05 ppm Au are determined by flame atomic absorption spectrophotometry.

10-element Inductively Coupled Plasma-Atomic Emission Spectrometry

Stream-sediment, mill tailing, and precipitate samples were analyzed for 10 elements (Ag, As, Au, Bi, Cd, Cu, Mo, Pb, Sb, and Zn) by the inductively coupled plasma-atomic emission spectrometry (ICP-AES) method of Motooka (1990). A 1.5 g sample was treated with 5.0 mL HCl and 1.0 mL of 30 percent hydrogen peroxide. After one hour, the digest was placed in a boiling water bath for 20 minutes. The digest was then cooled and 4.0 mL of a solution of ascorbic acid and potassium iodide were added. The sample-reagent combination was mixed and allowed to stand 20 minutes. 3.0 mL of diisobutylketone containing a tertiary amine hydrochloride (Aliquat 336) were added and the combined components shaken for 5 minutes. Following centrifuging, the separated organic phase was transferred to an auto sampler, drawn into the spectrometer, and analyzed. This is a partial digestion procedure, and results may be biased low when compared to other analytical techniques. Elemental upper and lower limits of determination for this ICP method are found in table 10.

40-element Inductively Coupled Plasma-Atomic Emission Spectrometry

Stream-sediment, mill tailing, and precipitate samples were analyzed for 40 elements by a inductively coupled plasma-atomic emission spectrometry (ICP-AES) method (Briggs, 1990) following multi-acid sample decomposition. The technique consists of adding 50 mg lutetium to a 0.200 g sample to form an internal standard which is digested to dryness with 3 mL HCl, 2 mL HNO_3, 1 mL $HClO_4$, and 2 mL HF at 110°C. Additional $HClO_4$ and water are added to the residue and taken to dryness at 150°C. 1 mL aqua regia is added and the sample is brought to 10.00 g with 1 percent HNO_3. The solution was heated at 95°C for 1 hour after which it was ananlyzed by ICP-AES. Elemental upper and lower limits of determination for this ICP method are given in table 9.

X-Ray Diffraction

Mineralogy of salt and precipitate samples was determined using standard x-ray powder diffraction techniques (Klug and Alexander, 1974). A representative portion of each sample was ground in a mortar and pestle to pass through a minus-200 mesh sieve (.074 mm). Random packed powder samples were prepared for analysis by front loading a conventional cavity-type diffraction mount. Samples 4chc359B and 4chc362P were x-rayed on a Philips APD-3720 diffractometer using Cu K_α radiation, a step size of 0.02° 2Θ, and a count time of 1 second. The balance of the salt and precipitate samples were x-rayed on a Siemans D-500 diffractometer using Cu K_α radiation, a step size of 0.02° 2Θ, and a count time of 15 seconds.

DATA STORAGE SYSTEM

The analytical results and related descriptive geological information (coded) were entered into the U.S. Geological Survey Branch of Geochemistry data base. Any or all of this information may be retrieved and converted to binary form (STATPAC) for computerized statistical analysis or publication (Van Trump and Miesch, 1977).

A digital version of this report is available on a 5.25 inch, 360K magnetic diskette as part B of this report (Kilburn and others, 1994). An ASCII file contains the text and analytical results are in database file (.dbf) format. Access to this information requires an IBM compatible computer using MS DOS, a 5.25-inch disk drive capable of handling 360K diskettes, and a database program able to import .dbf files.

DESCRIPTION OF DATA TABLES

The mineralogy of salt and precipitate samples are given in table 7. Tables 1-6 list the analytical results for each geochemical sample collected in the Holden area. Included in tables 1-6 are the sample ID number, latitude and longitude, and geochemical data. Data column identifiers (with the exception of pH and conductivity in table 1.) consist of two lines, the first giving the elemental symbol and units of measurement (%, ppm, and ppb) and the second specifying a code for the analytical method used for the element in that particular column. The analytical methods are coded as follows:

GF-AAS...graphite furnace atomic absorption spectrophotometry
IC...ion-chromatography
ICP-MS...inductively coupled plasma-mass spectrometry
ICP-40...40 element inductively coupled plasma emission spec.
ICP-10...10 element inductively coupled plasma emission spec.
SPEC...semiquantitative emission spectrography

In the data tables (tables 1-6), if a given element was looked for in a sample but not detected, a "less than" symbol (<) was entered in front of the lower limit of determination. If an element was measured above the highest reporting value, a "greater than" symbol (>) was entered in the tables in front of the upper limit of determination. A triple asterisk symbol "***" in the data column signifies that no analysis was performed for this element.

REFERENCES CITED

Adrian, B.M., Arbogast, B.F., Detra, D.E., and Mays, R.E., 1990, Direct-current arc emissions spectrographic methods for the semiquantitative analysis of rock, stream-sediment, soil, and heavy-mineral-concentrate samples, in Arbogast, B.F., Quality assurance manual for the Branch of Geochemistry: U.S. Geological Survey Open-File Report 90-668, p.100-106.

Briggs, P.H., 1990, Elemental analysis of geologic materials by inductively coupled plasma-atomic emission spectrometry, in Arbogast, B.F., Quality assurance manual for the Branch of Geochemistry: U.S. Geological Survey Open-File Report 90-668, p. 83-89.

Cater, F.W., 1982, Intrusive rocks of the Holden and Lucerne quadrangles, Washington--the relation of depth zones, composition, textures, and emplacement of plutons: U.S. Geological Survey Professional Paper 1220, 108 p.

Cater, F.W., and Crowder, D.F., 1967, Geologic map of the Holden quadrangle, Snohomish and Chelan Counties, Washington: U.S. Geological Survey Geologic Quadrangle Map GQ-646, scale 1:62,500.

Dragovich, J.D., and Derkey, R.E., 1994, A late Triassic island-arc setting for the Holden volcanogenic massive sulfide deposit, North Cascades, Washington: Washington Geology, v. 22, no. 1, p. 28-39.

Fishman, M., and Pyen, G., 1979, Determination of selected anions in water by ion chromatography: U.S. Geological Survey Water Resources Investigation 79-101, 30 p.

Guilbert, J.M., and Park, C.F., Jr., 1986, The geology of ore deposits: New York, W.H. Freeman and Co., p. 579-603.

Klug, H.P., and Alexander, L.E., 1974, X-ray diffraction procedures for polycrystalline and amorphous materials (2d ed.): New York, John Wiley and Sons, Inc., 966 p.

McWilliams, J.R., 1958, Mining methods and costs at the Holden mine, Chelan Division, Howe Sound Co., Chelan County, Wash.: U.S. Bureau of Mines Information Circular 7870, 44 p.

Motooka, J.M., 1990, Organometallic halide extraction applied to the analysis of geologic materials for 10 elements by inductively coupled plasma-atomic emission spectrometry, in Arbogast, B.F., Quality assurance manual for the Branch of Geochemistry: U.S. Geological Survey Open-File Report 90-668, p. 92-96.

Motooka, J.M., and Grimes, D.J., 1976, Analytical precision of one-sixth order semiquantitative spectrographic analysis: U.S. Geological Survey Circular 738, 25 p.

Nold, J.L., 1983, The Holden mine, a metamorphosed volcanogenic deposit in the Cascade Range of Washington: Economic Geology, v.78, no. 5, p. 944-953.

O'Leary, R.M., and Meier, A.L., 1990, Determination of gold in samples of rock, soil, stream sediment, and heavy-mineral-concentrate by flame and graphite furnace atomic absorption spectrophotometry following dissolution by HBr-Br_2, in Arbogast, B.F., Quality assurance manual for the Branch of Geochemistry: U.S. Geological Survey Open-File Report 90-668, p. 46-51.

VanTrump, George, Jr., and Miesch, A.T., 1977, The U.S. Geological Survey RASS-STATPAC system for management and statistical reduction of geochemical data: Computers and Geosciences, v.3, p. 475-488.

Youngberg, E.A., and Wilson, T.L., 1952, The Geology of the Holden mine: Economic Geology, v.47, no. 1, p. 1-12.

Table 1. Analytical data for raw water samples collected in the vicinity of the Holden mine, Chelan County, Washington.

	Sample	Latitude	Longitude	Temp. C	pH	Cond. uS/cm	F- ppm IC	Cl- ppm IC	SO4 ppm IC	NO3 ppm IC	PO4 ppm IC	Br ppm IC
1	4chc344	48 12 01	120 45 23	11	7.45	50	<0.05	0.8	7.3	0.15	<1	<0.1
2	4chc345	48 11 50	120 45 31	12.5	7.09	20	<0.05	0.25	4.7	<0.1	<1	<0.1
3	4chc350	48 11 46	120 45 34	19	2.82	1110	<0.05	0.65	456	<0.1	<1	<0.1
4	4chc348	48 11 45	120 46 20	6	7.42	20	<0.05	0.13	3.3	0.3	<1	<0.1
5	4chc349	48 11 51	120 46 18	6.5	7.41	20	<0.05	<0.1	3	<0.1	<1	<0.1
6	4chc364	48 11 55	120 46 28	11	2.9	1250	0.57	3.2	690	<0.1	<1	<0.1
7	4chc346	48 11 56	120 46 35	4.5	7.56	20	<0.05	<0.1	3.2	<0.1	<1	<0.1
8	4chc357	48 11 48	120 46 48	8	5.16	760	0.71	6.2	410	0.11	<1	<0.1
9	4chc358	48 11 57	120 47 00	13.5	5.01	800	0.7	6.2	406	0.11	<1	<0.1
10	4chc347	48 11 59	120 46 49	10	7.29	30	<0.05	0.21	4.8	<0.1	<1	<0.1
11	4chc367	48 12 00	120 47 28	13	7.02	20	<0.05	0.18	2.7	<0.1	<1	<0.1
12	4chc356	48 12 16	120 48 07	7	7.79	110	<0.05	0.15	12	<0.1	<1	<0.1
13	4chc355	48 12 42	120 49 24	9.5	7.36	20	<0.05	0.36	1.8	<0.1	<1	<0.1
14	4cjc354	48 12 04	120 35 37	12.5	7.45	30	<0.05	0.21	6.1	<0.1	<1	<0.1
15	4cic351	48 11 46	120 43 38	8.5	7.81	110	<0.05	0.12	8.3	<0.1	<1	<0.1
16	4cic352	48 11 33	120 42 38	9.5	7.38	30	<0.05	0.21	6.4	0.11	<1	<0.1
17	4cic353	48 11 26	120 42 08	9	7.69	30	<0.05	0.13	1.4	<0.1	<1	<0.1

Table 2. Analytical results for filtered and acidified water samples collected in the vicinity of the Holden mine, Chelan County, Washington.

	Sample	Latitude	Longitude	Ag ppb ICP-MS	Al ppb ICP-MS	As ppb ICP-MS	Au ppb ICP-MS	Ba ppb ICP-MS	Be ppb ICP-MS
1	4chc344	48 12 01	120 45 23	<0.1	10	<2	<0.1	6.1	<1
2	4chc345	48 11 50	120 45 31	<0.1	20	<2	<0.1	4.4	<1
3	4chc350	48 11 46	120 45 34	<0.1	1500	<2	<0.1	58	<1
4	4chc348	48 11 45	120 46 20	<0.1	<6	<2	<0.1	4.5	<1
5	4chc349	48 11 51	120 46 18	<0.1	<6	<2	<0.1	4.6	<1
6	4chc364	48 11 55	120 46 28	<0.1	>6000	<2	<0.1	13	<1
7	4chc346	48 11 56	120 46 35	<0.1	<6	<2	<0.1	5.8	<1
8	4chc357	48 11 48	120 46 48	<0.1	1000	<2	<0.1	12	<1
9	4chc358	48 11 57	120 47 00	<0.1	940	<2	<0.1	11	<1
10	4chc347	48 11 59	120 46 49	<0.1	10	<2	<0.1	4.2	<1
11	4chc367	48 12 00	120 47 28	<0.1	20	<2	<0.1	4.1	<1
12	4chc356	48 12 16	120 48 07	<0.1	<6	<2	<0.1	7.2	<1
13	4chc355	48 12 42	120 49 24	<0.1	<6	<2	<0.1	4.1	<1
14	4cjc354	48 12 04	120 35 37	<0.1	21	<2	<0.1	5.3	<1
15	4cic351	48 11 46	120 43 38	<0.1	<6	<2	<0.1	7.8	<1
16	4cic352	48 11 33	120 42 38	<0.1	20	<2	<0.1	4.7	<1
17	4cic353	48 11 26	120 42 08	<0.1	<6	<2	<0.1	6.1	<1

	Sample	Bi ppb ICP-MS	Ca ppb ICP-MS	Cd ppb ICP-MS	Ce ppb ICP-MS	Co ppb ICP-MS	Cr ppb ICP-MS	Cs ppb ICP-MS	Cu ppb ICP-MS
1	4chc344	<0.6	7000	<1	<0.1	<0.1	<1	<0.1	8.3
2	4chc345	<0.6	<6000	<1	<0.1	0.1	<1	<0.1	2.3
3	4chc350	<0.6	62000	<1	2.1	2	<1	0.4	21
4	4chc348	<0.6	<6000	<1	<0.1	<0.1	<1	<0.1	0.59
5	4chc349	<0.6	<6000	<1	<0.1	<0.1	<1	<0.1	0.3
6	4chc364	<0.6	39000	6.8	21	16	<1	0.5	53
7	4chc346	<0.6	<6000	<1	<0.1	<0.1	<1	<0.1	0.59
8	4chc357	<0.6	72000	21	2.4	3.6	<1	0.4	570
9	4chc358	<0.6	73000	21	2.5	3.8	<1	0.4	580
10	4chc347	<0.6	<6000	<1	<0.1	<0.1	<1	<0.1	5
11	4chc367	<0.6	<6000	<1	<0.1	<0.1	<1	<0.1	0.62
12	4chc356	<0.6	10000	<1	<0.1	<0.1	<1	<0.1	0.3
13	4chc355	<0.6	<6000	<1	<0.1	<0.1	<1	<0.1	1.4
14	4cjc354	<0.6	<6000	<1	<0.1	<0.1	<1	<0.1	1.4
15	4cic351	<0.6	10000	<1	<0.1	<0.1	<1	<0.1	0.98
16	4cic352	<0.6	<6000	<1	<0.1	0.1	<1	<0.1	1.6
17	4cic353	<0.6	<6000	<1	<0.1	<0.1	<1	<0.1	<0.1

	Sample	Dy ppb ICP-MS	Er ppb ICP-MS	Eu ppb ICP-MS	Fe ppb ICP-MS	Ga ppb ICP-MS	Gd ppb ICP-MS	Ge ppb ICP-MS	Hf ppb ICP-MS
1	4chc344	<0.1	<0.1	<0.1	<100	<0.1	<0.1	<0.1	<0.1
2	4chc345	<0.1	<0.1	<0.1	320	<0.1	<0.1	<0.1	<0.1
3	4chc350	0.4	<0.1	0.1	23000	<0.1	0.4	<0.1	<0.1
4	4chc348	<0.1	<0.1	<0.1	<100	<0.1	<0.1	<0.1	<0.1
5	4chc349	<0.1	<0.1	<0.1	<100	<0.1	<0.1	<0.1	<0.1
6	4chc364	3.1	1.4	0.6	50000	0.1	3.1	<0.1	<0.1
7	4chc346	<0.1	<0.1	<0.1	<100	<0.1	<0.1	<0.1	<0.1
8	4chc357	0.9	<0.1	0.2	580	<0.1	0.9	0.1	<0.1
9	4chc358	0.8	<0.1	0.2	370	<0.1	0.9	<0.1	<0.1
10	4chc347	<0.1	<0.1	<0.1	<100	<0.1	<0.1	<0.1	<0.1
11	4chc367	<0.1	<0.1	<0.1	<100	<0.1	<0.1	<0.1	<0.1
12	4chc356	<0.1	<0.1	<0.1	<100	<0.1	<0.1	<0.1	<0.1
13	4chc355	<0.1	<0.1	<0.1	<100	<0.1	<0.1	<0.1	<0.1
14	4cjc354	<0.1	<0.1	<0.1	200	<0.1	<0.1	<0.1	<0.1
15	4cic351	<0.1	<0.1	<0.1	<100	<0.1	<0.1	<0.1	<0.1
16	4cic352	<0.1	<0.1	<0.1	200	<0.1	<0.1	<0.1	<0.1
17	4cic353	<0.1	<0.1	<0.1	<100	<0.1	<0.1	<0.1	<0.1

Table 2. Analytical results for filtered and acidified water samples collected in the vicinity of the Holden mine, Chelan County, Washington.--cont.

	Sample	Ho ppb ICP-MS	Ir ppb ICP-MS	K ppb ICP-MS	La ppb ICP-MS	Li ppb ICP-MS	Mg ppb ICP-MS	Mn ppb ICP-MS	Mo ppb ICP-MS
1	4chc344	<0.1	<0.1	400	<0.1	<0.2	560	<0.9	0.7
2	4chc345	<0.1	<0.1	200	<0.1	<0.2	360	5.4	0.5
3	4chc350	<0.1	<0.1	>2000	0.8	8.1	8900	140	<0.1
4	4chc348	<0.1	<0.1	400	<0.1	<0.2	390	<0.9	0.5
5	4chc349	<0.1	<0.1	400	<0.1	<0.2	400	<0.9	0.4
6	4chc364	0.7	<0.1	>2000	8.6	28	17000	1000	<0.1
7	4chc348	<0.1	<0.1	300	<0.1	<0.2	320	<0.9	0.4
8	4chc357	0.2	<0.1	>2000	0.8	25	7900	350	0.6
9	4chc358	0.2	<0.1	>2000	0.8	28	8000	350	0.5
10	4chc347	<0.1	<0.1	<200	<0.1	0.3	320	3	0.5
11	4chc367	<0.1	<0.1	<200	<0.1	0.2	270	2	0.5
12	4chc356	<0.1	<0.1	790	<0.1	0.6	1700	<0.9	1.6
13	4chc355	<0.1	<0.1	<200	<0.1	<0.2	210	<0.9	0.2
14	4cjc354	<0.1	<0.1	300	<0.1	0.2	490	3.5	0.4
15	4cic351	<0.1	<0.1	500	<0.1	0.3	1600	<0.9	0.5
16	4cic352	<0.1	<0.1	200	<0.1	<0.2	480	5.5	0.5
17	4cic353	<0.1	<0.1	200	<0.1	0.3	540	<0.9	0.2

	Sample	Na ppb ICP-MS	Nb ppb ICP-MS	Nd ppb ICP-MS	Ni ppb ICP-MS	Os ppb ICP-MS	Pb ppb ICP-MS	Pd ppb ICP-MS	Pr ppb ICP-MS
1	4chc344	600	<0.1	<0.1	<3	<0.1	<0.2	<0.1	<0.1
2	4chc345	400	<0.1	<0.1	<3	<0.1	<0.2	<0.1	<0.1
3	4chc350	2900	<0.1	1.7	4	<0.1	1.4	<0.1	0.3
4	4chc348	400	<0.1	<0.1	<3	<0.1	<0.2	<0.1	<0.1
5	4chc349	400	<0.1	<0.1	<3	<0.1	<0.2	<0.1	<0.1
6	4chc364	4200	<0.1	10	18	<0.1	2.7	<0.1	2.6
7	4chc346	300	<0.1	<0.1	<3	<0.1	<0.2	<0.1	<0.1
8	4chc357	>5000	<0.1	2.1	4	<0.1	21	<0.1	0.4
9	4chc358	>5000	<0.1	2.2	4	<0.1	22	<0.1	0.4
10	4chc347	400	<0.1	<0.1	<3	<0.1	<0.2	<0.1	<0.1
11	4chc367	300	<0.1	<0.1	<3	<0.1	<0.2	<0.1	<0.1
12	4chc356	830	<0.1	<0.1	<3	<0.1	<0.2	<0.1	<0.1
13	4chc355	950	<0.1	<0.1	<3	<0.1	<0.2	<0.1	<0.1
14	4cjc354	500	<0.1	<0.1	<3	<0.1	<0.2	<0.1	<0.1
15	4cic351	970	<0.1	<0.1	<3	<0.1	<0.2	<0.1	<0.1
16	4cic352	400	<0.1	<0.1	<3	<0.1	<0.2	<0.1	<0.1
17	4cic353	400	<0.1	<0.1	<3	<0.1	<0.2	<0.1	<0.1

	Sample	Pt ppb ICP-MS	Rb ppb ICP-MS	Re ppb ICP-MS	Rh ppb ICP-MS	Ru ppb ICP-MS	Sb ppb ICP-MS	Sc ppb ICP-MS	Sm ppb ICP-MS
1	4chc344	<0.1	0.7	<0.1	<0.1	<0.1	<0.1	<5	<0.1
2	4chc345	<0.1	0.5	<0.1	<0.1	<0.1	0.1	<5	<0.1
3	4chc350	<0.1	13	<0.1	<0.1	<0.1	<0.1	<5	0.3
4	4chc348	<0.1	0.5	<0.1	<0.1	<0.1	<0.1	<5	<0.1
5	4chc349	<0.1	0.5	<0.1	<0.1	<0.1	<0.1	<5	<0.1
6	4chc364	<0.1	10	<0.1	<0.1	<0.1	<0.1	<5	2.3
7	4chc346	<0.1	0.4	<0.1	<0.1	<0.1	<0.1	<5	<0.1
8	4chc357	<0.1	6.3	<0.1	<0.1	<0.1	<0.1	<5	0.6
9	4chc358	<0.1	6.5	<0.1	<0.1	<0.1	<0.1	<5	0.8
10	4chc347	<0.1	0.4	<0.1	<0.1	<0.1	<0.1	<5	<0.1
11	4chc367	<0.1	0.4	<0.1	<0.1	<0.1	<0.1	<5	<0.1
12	4chc356	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<5	<0.1
13	4chc355	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<5	<0.1
14	4cjc354	<0.1	0.5	<0.1	<0.1	<0.1	<0.1	<5	<0.1
15	4cic351	<0.1	0.4	<0.1	<0.1	<0.1	<0.1	<5	<0.1
16	4cic352	<0.1	0.4	<0.1	<0.1	<0.1	<0.1	<5	<0.1
17	4cic353	<0.1	0.4	<0.1	<0.1	<0.1	<0.1	<5	<0.1

Table 2. Analytical results for filtered and acidified water samples collected in the vicinity of the Holden mine, Chelan County, Washington.--cont.

	Sample	Sn ppb ICP-MS	Sr ppb ICP-MS	Ta ppb ICP-MS	Tb ppb ICP-MS	Te ppb ICP-MS	Th ppb ICP-MS	Ti ppb ICP-MS	Tl ppb ICP-MS
1	4chc344	<0.2	41	<0.1	<0.1	<1	<0.5	<3	<0.1
2	4chc345	<0.2	17	<0.1	<0.1	<1	<0.5	<3	<0.1
3	4chc350	<0.2	250	<0.1	<0.1	<1	<0.5	4	0.3
4	4chc348	<0.2	14	<0.1	<0.1	<1	<0.5	<3	<0.1
5	4chc349	<0.2	13	<0.1	<0.1	<1	<0.5	<3	<0.1
6	4chc364	<0.2	280	<0.1	0.6	<1	<0.5	4	0.2
7	4chc348	<0.2	12	<0.1	<0.1	<1	<0.5	<3	<0.1
8	4chc357	<0.2	460	<0.1	0.1	<1	<0.5	4	0.1
9	4chc358	<0.2	460	<0.1	0.2	<1	<0.5	4	<0.1
10	4chc347	<0.2	18	<0.1	<0.1	<1	<0.5	<3	<0.1
11	4chc367	<0.2	16	<0.1	<0.1	<1	<0.5	<3	<0.1
12	4chc356	<0.2	52	<0.1	<0.1	<1	<0.5	<3	<0.1
13	4chc355	<0.2	11	<0.1	<0.1	<1	<0.5	<3	<0.1
14	4cjc354	<0.2	24	<0.1	<0.1	<1	<0.5	<3	<0.1
15	4cic351	<0.2	83	<0.1	<0.1	<1	<0.5	<3	<0.1
16	4cic352	<0.2	23	<0.1	<0.1	<1	<0.5	<3	<0.1
17	4cic353	<0.2	30	<0.1	<0.1	<1	<0.5	<3	<0.1

	Sample	Tm ppb ICP-MS	U ppb ICP-MS	V ppb ICP-MS	W ppb ICP-MS	Y ppb ICP-MS	Yb ppb ICP-MS	Zn ppb ICP-MS	Zr ppb ICP-MS
1	4chc344	<0.1	<0.1	<1	<0.1	<0.1	<0.1	11	<0.1
2	4chc345	<0.1	<0.1	<1	<0.1	<0.1	<0.1	18	<0.1
3	4chc350	<0.1	0.4	<1	<0.1	1.7	0.2	130	<0.1
4	4chc348	<0.1	<0.1	<1	<0.1	<0.1	<0.1	2	<0.1
5	4chc349	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<2	<0.1
6	4chc364	0.2	1.2	<1	0.1	20	1	3800	<0.1
7	4chc346	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<2	<0.1
8	4chc357	<0.1	2.7	<1	<0.1	4	0.4	4800	<0.1
9	4chc358	<0.1	2.5	<1	<0.1	3.9	0.3	4900	<0.1
10	4chc347	<0.1	<0.1	<1	<0.1	<0.1	<0.1	37	<0.1
11	4chc367	<0.1	<0.1	<1	0.5	<0.1	<0.1	4	<0.1
12	4chc356	<0.1	0.3	<1	<0.1	<0.1	<0.1	<2	<0.1
13	4chc355	<0.1	<0.1	<1	<0.1	<0.1	<0.1	3	<0.1
14	4cjc354	<0.1	<0.1	<1	<0.1	<0.1	<0.1	14	<0.1
15	4cic351	<0.1	0.5	<1	<0.1	<0.1	<0.1	<2	<0.1
16	4cic352	<0.1	<0.1	<1	<0.1	<0.1	<0.1	13	<0.1
17	4cic353	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<2	<0.1

Table 3. Analytical results for stream sediment samples collected in the vicinity of the Holden mine, Chelan County, Washington.

	Sample	Latitude	Longitude	Al % ICP-40	Ca % ICP-40	Fe % ICP-40	K % ICP-40	Mg % ICP-40	Na % ICP-40
1	4chc344	48 12 01	120 45 23	8.3	4.3	9.4	0.74	2.5	2.2
2	4chc345	48 11 50	120 45 31	7.8	2.9	5	1	2	2.4
3	4chc350	48 11 46	120 45 34	3.4	1	15	0.75	0.82	0.98
4	4chc348	48 11 45	120 46 20	7.3	3.9	7.1	0.77	4.9	2.3
5	4chc349	48 11 51	120 46 18	6.3	3.2	7.5	0.75	4	2
6	4chc348	48 11 56	120 46 35	5.9	2.7	6.2	0.74	2.6	1.7
7	4chc347	48 11 59	120 46 49	8.3	3.9	7.1	0.82	2.4	2.5
8	4chc367	48 12 00	120 47 28	7.8	3.7	9.9	0.73	2.2	2.4
9	4chc356	48 12 16	120 48 07	8.7	3.7	4.7	1.2	2	2.9
10	4chc355	48 12 42	120 49 24	8.6	3.7	6.3	0.88	2.4	2.3
11	4cjc354	48 12 04	120 35 37	7.6	3.2	6	0.92	1.9	2.3
12	4cic351	48 11 46	120 43 38	8.9	4	6.6	0.75	2.3	2.4
13	4cic352	48 11 33	120 42 38	7.5	3.6	7.1	0.76	2.4	2.2
14	4cic353	48 11 26	120 42 08	8.8	3.6	4	1.2	1.8	2.8

	Sample	P % ICP-40	Ti % ICP-40	Mn ppm ICP-40	Ag ppm ICP-40	As ppm ICP-40	Au ppm ICP-40	Ba ppm ICP-40	Be ppm ICP-40
1	4chc344	0.11	0.78	980	<2	<10	<8	380	1
2	4chc345	0.06	0.39	860	<2	10	<8	540	1
3	4chc350	0.03	0.13	380	<2	<10	<8	220	<1
4	4chc348	0.12	0.59	1300	<2	<10	<8	390	1
5	4chc349	0.1	0.54	1200	<2	<10	<8	490	1
6	4chc348	0.08	0.36	830	<2	<10	<8	210	<1
7	4chc347	0.08	0.81	1400	<2	13	<8	390	1
8	4chc367	0.08	1.2	1600	<2	12	<8	340	1
9	4hcc356	0.04	0.73	980	<2	<10	<8	480	1
10	4chc355	0.08	0.61	1300	<2	<10	<8	470	1
11	4cjc354	0.09	0.57	980	<2	<10	<8	480	1
12	4cic351	0.08	0.76	900	<2	<10	<8	350	1
13	4cic352	0.07	0.75	1200	<2	<10	<8	410	1
14	4cic353	0.06	0.48	790	<2	<10	<8	450	1

	Sample	Bi ppm ICP-40	Cd ppm ICP-40	Ce ppm ICP-40	Co ppm ICP-40	Cr ppm ICP-40	Cu ppm ICP-40	Eu ppm ICP-40	Ga ppm ICP-40
1	4chc344	<10	2	21	30	77	31	<2	22
2	4chc345	<10	<2	22	19	70	140	<2	17
3	4chc350	<10	<2	11	4	18	200	<2	14
4	4chc348	<10	<2	32	42	280	56	<2	17
5	4chc349	<10	<2	29	33	220	92	<2	17
6	4chc346	<10	8	23	23	110	1000	<2	15
7	4chc347	<10	2	26	26	85	240	<2	20
8	4chc367	<10	2	28	27	97	37	<2	23
9	4chc356	<10	<2	24	18	36	12	<2	20
10	4chc355	<10	<2	21	27	79	74	<2	19
11	4cjc354	<10	<2	35	19	74	150	<2	18
12	4cic351	<10	<2	21	24	44	26	<2	22
13	4cic352	<10	<2	27	24	93	130	<2	19
14	4cic353	<10	<2	42	16	52	13	<2	20

Table 3. Analytical results for stream sediment samples collected in the vicinity of the Holden mine, Chelan County, Washington.--cont.

	Sample	Ho ppm ICP-40	La ppm ICP-40	Li ppm ICP-40	Mo ppm ICP-40	Nb ppm ICP-40	Nd ppm ICP-40	Ni ppm ICP-40	Pb ppm ICP-40
1	4chc344	<4	11	22	<2	8	14	29	7
2	4chc345	<4	12	23	2	9	13	30	24
3	4chc350	<4	6	12	12	<4	6	2	66
4	4chc348	<4	17	26	<2	13	21	140	7
5	4chc349	<4	14	21	2	11	16	100	29
6	4chc346	<4	13	19	14	9	13	51	66
7	4chc347	<4	15	19	<2	12	17	29	14
8	4chc367	<4	16	17	<2	12	18	28	11
9	4chc356	<4	14	29	<2	13	14	20	7
10	4chc355	<4	12	22	<2	11	14	31	17
11	4cjc354	<4	20	20	4	10	19	25	25
12	4cic351	<4	12	26	<2	11	14	20	5
13	4cic352	<4	15	19	<2	10	18	32	18
14	4cic353	<4	24	33	<2	12	23	22	8

	Sample	Sc ppm ICP-40	Sn ppm ICP-40	Sr ppm ICP-40	Ta ppm ICP-40	Th ppm ICP-40	U ppm ICP-40	V ppm ICP-40	Y ppm ICP-40
1	4chc344	23	<5	470	<40	<4	<100	370	17
2	4chc345	18	<5	350	<40	<4	<100	150	12
3	4chc350	8	<5	130	<40	<4	<100	70	2
4	4chc348	25	<5	360	<40	4	<100	190	20
5	4chc349	21	<5	290	<40	<4	<100	190	17
6	4chc346	15	<5	260	<40	<4	<100	120	12
7	4chc347	27	<5	400	<40	<4	<100	250	18
8	4chc367	26	<5	410	<40	5	<100	370	17
9	4chc356	16	<5	490	<40	5	<100	130	14
10	4chc355	26	<5	360	<40	<4	<100	230	16
11	4cjc354	18	<5	370	<40	5	<100	180	17
12	4cic351	21	<5	480	<40	<4	<100	230	15
13	4cic352	23	<5	370	<40	4	<100	230	17
14	4cic353	14	<5	520	<40	8	<100	110	16

	Sample	Yb ppm ICP-40	Zn ppm ICP-40	Ag ppm ICP-10	As ppm ICP-10	Au ppm ICP-10	Bi ppm ICP-10	Cd ppm ICP-10	Cu ppm ICP-10
1	4chc344	1	120	<0.067	<1	<0.1	<1	0.16	23
2	4chc345	2	280	0.17	4.7	<0.1	<1	0.6	110
3	4chc350	<1	250	1.2	<1	0.11	<1	<0.05	160
4	4chc348	2	110	<0.067	<1	<0.1	<1	0.081	43
5	4chc349	2	150	0.3	<1	<0.1	<1	0.087	72
6	4chc346	1	1100	1.2	<1	<0.1	<1	4.8	750
7	4chc347	2	270	<0.067	6.6	<0.1	<1	0.56	200
8	4chc367	2	130	<0.067	6.6	<0.1	<1	0.12	27
9	4chc356	1	110	<0.067	<1	<0.1	<1	0.085	7.2
10	4chc355	2	180	<0.067	3.1	<0.1	<1	0.55	59
11	4cjc354	1	330	0.098	3.5	<0.1	<1	0.63	120
12	4cic351	1	110	<0.067	<1	<0.1	<1	0.063	20
13	4cic352	2	230	0.11	3.1	<0.1	<1	0.49	110
14	4cic353	1	82	0.45	<1	<0.1	<1	<0.05	9

Table 3. Analytical results for stream sediment samples collected in the vicinity of the Holden mine, Chelan County, Washington.--cont.

	Sample	Mo ppm ICP-10	Pb ppm ICP-10	Sb ppm ICP-10	Zn ppm ICP-10	Au ppm GF-AAS
1	4chc344	0.57	2.1	<1	69	0.024
2	4chc345	1.9	11	<1	230	0.1
3	4chc350	7.7	31	<1	200	0.4
4	4chc348	0.59	1.6	<1	62	0.004
5	4chc349	2.7	13	<1	90	0.35
6	4chc346	2.3	36	<1	790	0.45
7	4chc347	0.93	8.5	<1	210	0.02
8	4chc367	1.3	6.2	<1	76	0.006
9	4chc356	0.58	1.3	<1	47	0.006
10	4chc355	0.76	8.6	<1	130	0.004
11	4cjc354	1.8	11	<1	270	0.1
12	4cic351	0.43	1.4	<1	53	0.006
13	4cic352	1.8	7.5	<1	170	0.15
14	4cic353	0.35	1.8	2.9	39	0.008

Table 4. Analytical results for concentrate samples collected in the vicinity of the Holden mine, Chelan County, Washington.

	Sample	Latitude	Longitude	Ca % SPEC	Fe % SPEC	Mg % SPEC	Na % SPEC	P % SPEC	Ti % SPEC
1	4chc344	48 12 01	120 45 23	10	3	2	0.5	3	>2
2	4chc345	48 11 50	120 45 31	7	3	1.5	<0.5	3	>2
3	4chc350	48 11 46	120 45 34	1.5	5	1.5	<0.5	<0.5	>2
4	4chc348	48 11 45	120 46 20	10	3	5	0.5	7	>2
5	4chc349	48 11 51	120 46 18	10	2	3	<0.5	5	>2
6	4chc346	48 11 56	120 46 35	3	30	1	<0.5	0.7	>2
7	4chc347	48 11 59	120 46 49	7	1.5	1	<0.5	5	>2
8	4chc367	48 12 00	120 47 28	7	3	1.5	0.5	2	>2
9	4chc356	48 12 16	120 48 07	15	2	5	<0.5	0.7	>2
10	4chc355	48 12 42	120 49 24	7	5	2	0.5	1.5	>2
11	4cjc354	48 12 04	120 35 37	7	2	1	<0.5	5	>2
12	4cic351	48 11 46	120 43 38	10	2	1.5	0.7	7	>2
13	4cic352	48 11 33	120 42 38	10	3	2	0.5	3	>2
14	4cic353	48 11 26	120 42 08	15	3	0.7	1	5	>2

	Sample	Ag ppm SPEC	As ppm SPEC	Au ppm SPEC	B ppm SPEC	Ba ppm SPEC	Be ppm SPEC	Bi ppm SPEC	Cd ppm SPEC
1	4chc344	<1	<500	<20	150	300	<2	<20	<50
2	4chc345	<1	<500	<20	200	3000	<2	<20	<50
3	4chc350	<1	<500	<20	150	>10000	<2	<20	<50
4	4chc348	<1	<500	<20	200	300	<2	<20	<50
5	4chc349	<1	<500	<20	200	3000	<2	<20	<50
6	4chc346	5	<500	<20	70	>10000	<2	<20	300
7	4chc347	<1	<500	<20	200	1500	<2	<20	<50
8	4chc367	<1	<500	<20	300	300	<2	<20	<50
9	4chc356	<1	<500	<20	300	300	<2	<20	<50
10	4chc355	<1	<500	<20	500	300	<2	<20	<50
11	4cjc354	<1	<500	<20	150	1500	<2	<20	<50
12	4cic351	<1	<500	<20	20	300	<2	<20	<50
13	4cic352	<1	<500	<20	300	700	<2	<20	<50
14	4cic353	<1	<500	<20	<20	300	<2	<20	<50

	Sample	Co ppm SPEC	Cr ppm SPEC	Cu ppm SPEC	Ga ppm SPEC	Ge ppm SPEC	La ppm SPEC	Mn ppm SPEC	Mo ppm SPEC
1	4chc344	50	200	50	20	<20	<100	700	<10
2	4chc345	20	300	500	20	<20	100	700	70
3	4chc350	<20	150	2000	30	<20	<100	700	700
4	4chc348	30	1000	300	20	<20	200	700	20
5	4chc349	20	1000	300	15	<20	100	500	<10
6	4chc346	500	200	5000	50	<20	100	300	10
7	4chc347	20	200	300	30	<20	<100	500	<10
8	4chc367	<20	200	70	30	<20	100	700	<10
9	4chc356	<20	300	<10	20	<20	<100	1000	<10
10	4chc355	20	200	70	50	<20	<100	1000	<10
11	4cjc354	<20	150	300	15	<20	<100	300	20
12	4cic351	<20	150	70	20	<20	150	500	<10
13	4cic352	<20	500	700	20	<20	<100	700	<10
14	4cic353	<20	50	<10	20	<20	300	700	<10

Table 4. Analytical results for concentrate samples collected in the vicinity of the Holden mine, Chelan County, Washington.--cont.

	Sample	Nb ppm SPEC	Ni ppm SPEC	Pb ppm SPEC	Sb ppm SPEC	Sc ppm SPEC	Sn ppm SPEC	Sr ppm SPEC	Th ppm SPEC
1	4chc344	<50	30	<20	<200	10	<20	700	<200
2	4chc345	100	50	30	<200	30	20	700	<200
3	4chc350	200	<10	50	<200	30	70	200	<200
4	4chc348	50	150	<20	<200	50	<20	700	<200
5	4chc349	50	70	<20	<200	70	20	700	<200
6	4chc346	50	50	500	<200	20	<20	500	<200
7	4chc347	50	<10	20	<200	30	<20	300	<200
8	4chc367	<50	30	<20	<200	30	<20	700	<200
9	4chc356	50	50	20	<200	30	<20	500	<200
10	4chc355	<50	50	50	<200	20	<20	700	<200
11	4cjc354	70	<10	<20	<200	50	20	300	<200
12	4cic351	50	<10	<20	<200	20	<20	500	<200
13	4cic352	50	30	20	<200	20	<20	500	<200
14	4cic353	70	<10	<20	<200	<10	<20	500	<200

	Sample	V ppm SPEC	W ppm SPEC	Y ppm SPEC	Zn ppm SPEC	Zr ppm SPEC	Pd ppm SPEC	Pt ppm SPEC
1	4chc344	300	<50	100	<500	>2000	<100	<100
2	4chc345	300	<50	300	1500	>2000	<100	<100
3	4chc350	500	70	150	2000	>2000	<100	<100
4	4chc348	300	70	300	<500	>2000	<100	<100
5	4chc349	300	50	300	2000	>2000	<100	<100
6	4chc346	200	<50	100	10000	>2000	<100	<100
7	4chc347	300	<50	200	<500	>2000	<100	<100
8	4chc367	300	100	150	1000	>2000	<100	<100
9	4chc356	300	50	200	<500	>2000	<100	<100
10	4chc355	300	<50	70	1500	2000	<100	<100
11	4cjc354	300	100	500	1500	>2000	<100	<100
12	4cic351	300	100	200	<500	>2000	<100	<100
13	4cic352	300	<50	150	1000	>2000	<100	<100
14	4cic353	200	300	300	<500	>2000	<100	<100

Table 5. Analytical results for salt and precipitate samples collected in the vicinity of the Holden mine, Chelan County, Washington.

	Sample	Latitude	Longitude	Al % ICP-40	Ca % ICP-40	Fe % ICP-40	K % ICP-40	Mg % ICP-40	Na % ICP-40
1	4chc359A	48 11 48	120 45 32	4.6	0.38	1	0.05	3.1	1.1
2	4chc359B	48 11 48	120 45 32	1.3	7	0.65	0.16	0.36	0.25
3	4chc366A	48 11 52	120 46 19	5.3	0.61	0.73	0.12	3.4	0.55
4	4chc366B	48 11 52	120 46 19	3	1.2	24	0.45	0.84	0.89
5	4chc365P	48 11 53	120 46 20	2.2	0.77	27	0.91	0.62	0.6
6	4chc364P	48 11 55	120 46 28	2.2	0.8	32	0.45	0.56	0.64
7	4chc363A	48 11 55	120 46 34	4.2	0.67	2.9	0.37	1.4	0.65
8	4chc363B	48 11 55	120 46 34	2.9	0.78	8.3	0.44	1.2	0.55
9	4chc362P	48 11 51	120 46 59	15	0.65	5.9	0.24	0.3	0.58

	Sample	P % ICP-40	Ti % ICP-40	Mn ppm ICP-40	Ag ppm ICP-40	As ppm ICP-40	Au ppm ICP-40	Ba ppm ICP-40	Be ppm ICP-40
1	4chc359A	0.03	0.02	1400	<2	<10	<8	15	1
2	4chc359B	0.01	0.05	180	<2	<10	<8	47	<1
3	4chc366A	0.02	0.02	2400	<2	<10	<8	42	2
4	4chc366B	0.03	0.15	430	<2	<10	<8	150	<1
5	4chc365P	0.05	0.18	310	<2	<10	<8	47	<1
6	4chc364P	0.03	0.19	280	<2	<10	<8	180	<1
7	4chc363A	0.09	0.11	590	6	<10	<8	40	<1
8	4chc363B	0.09	0.11	520	13	<10	<8	33	<1
9	4chc362P	0.02	0.08	190	<2	<10	<8	82	1

	Sample	Bi ppm ICP-40	Cd ppm ICP-40	Ce ppm ICP-40	Co ppm ICP-40	Cr ppm ICP-40	Cu ppm ICP-40	Eu ppm ICP-40	Ga ppm ICP-40
1	4chc359A	<10	63	6	64	20	5800	<2	<4
2	4chc359B	<10	3	23	6	19	94	<2	<4
3	4chc366A	<10	16	48	33	7	650	<2	4
4	4chc366B	<10	<2	14	10	24	110	<2	15
5	4chc365P	<10	<2	8	7	46	370	<2	17
6	4chc364P	<10	<2	7	8	43	160	<2	20
7	4chc363A	<10	370	6	87	16	38000	<2	6
8	4chc363B	<10	200	8	61	17	43000	<2	8
9	4chc362P	<10	<2	6	4	15	710	<2	<4

	Sample	Ho ppm ICP-40	La ppm ICP-40	Li ppm ICP-40	Mo ppm ICP-40	Nb ppm ICP-40	Nd ppm ICP-40	Ni ppm ICP-40	Pb ppm ICP-40
1	4chc359A	<4	3	96	<2	5	<4	37	<4
2	4chc359B	<4	11	7	2	<4	16	9	<4
3	4chc366A	<4	28	61	<2	7	29	68	<4
4	4chc366B	<4	7	12	<2	<4	8	13	20
5	4chc365P	<4	4	7	<2	<4	4	12	33
6	4chc364P	<4	4	5	<2	<4	<4	14	21
7	4chc363A	<4	4	42	55	<4	5	82	120
8	4chc363B	<4	3	21	280	<4	4	36	98
9	4chc362P	<4	3	5	17	11	4	4	160

Table 5. Analytical results for salt and precipitate samples collected in the vicinity of the Holden mine, Chelan County, Washington.--cont.

	Sample	Sc ppm ICP-40	Sn ppm ICP-40	Sr ppm ICP-40	Ta ppm ICP-40	Th ppm ICP-40	U ppm ICP-40	V ppm ICP-40	Y ppm ICP-40
1	4chc359A	10	<5	41	<40	<4	<100	8	14
2	4chc359B	<2	<5	180	<40	<4	<100	13	9
3	4chc366A	10	<5	40	<40	10	<100	8	66
4	4chc366B	8	<5	130	<40	5	<100	63	5
5	4chc365P	8	6	95	<40	4	<100	110	<2
6	4chc364P	8	5	100	<40	6	<100	75	<2
7	4chc363A	11	<5	70	<40	<4	<100	37	14
8	4chc363B	12	7	69	<40	<4	<100	47	4
9	4chc362P	11	<5	73	<40	<4	<100	43	4

	Sample	Yb ppm ICP-40	Zn ppm ICP-40	Ag ppm ICP-10	As ppm ICP-10	Au ppm ICP-10	Bi ppm ICP-10	Cd ppm ICP-10	Cu ppm ICP-10
1	4chc359A	2	15000	<0.67	<10	<1	<10	63	5500
2	4chc359B	1	320	***	***	***	***	***	***
3	4chc366A	6	3900	<0.067	<1	<0.1	<1	16	640
4	4chc366B	<1	480	0.32	3	<0.1	<1	0.79	100
5	4chc365P	<1	110	1	9.6	0.17	1.1	0.094	360
6	4chc364P	<1	130	0.21	12	<0.1	<1	0.15	130
7	4chc363A	<1	40000	<0.67	<10	<1	<10	360	>11000
8	4chc363B	<1	30000	7.3	<10	<1	<10	190	>11000
9	4chc362P	<1	200	1.6	<1	<0.1	<1	0.63	660

	Sample	Mo ppm ICP-10	Pb ppm ICP-10	Sb ppm ICP-10	Zn ppm ICP-10
1	4chc359A	2.6	<10	<10	6400
2	4chc359B	***	***	***	***
3	4chc366A	1.2	<1	<1	>2400
4	4chc366B	2.3	13	<1	370
5	4chc365P	4.1	29	<1	61
6	4chc364P	1.1	5.3	<1	0.85
7	4chc363A	<1	130	<10	120
8	4chc363B	<1	120	<10	24
9	4chc362P	19	160	<1	190

Table 6. Analytical results for mill tailings collected at the Holden mine, Chelan County, Washington.

Sample	Latitude	Longitude	Al %	Ca %	Fe %	K %
			ICP-40	ICP-40	ICP-40	ICP-40
4chc360	48 11 52	120 45 37	4.4	1.6	4.7	0.74

Mg %	Na %	P %	Ti %	Mn ppm	Ag ppm	As ppm
ICP-40	ICP-40	ICP-40	ICP-40	ICP-40	ICP-40	ICP-40
0.88	1.4	0.02	0.15	480	<2	<10

Au ppm	Ba ppm	Be ppm	Bi ppm	Cd ppm	Ce ppm	Co ppm
ICP-40	ICP-40	ICP-40	ICP-40	ICP-40	ICP-40	ICP-40
<8	720	<1	<10	<2	13	3

Cr ppm	Cu ppm	Eu ppm	Ga ppm	Ho ppm	La ppm	Li ppm
ICP-40	ICP-40	ICP-40	ICP-40	ICP-40	ICP-40	ICP-40
24	110	<2	12	<4	7	11

Mo ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Sc ppm	Sn ppm
ICP-40	ICP-40	ICP-40	ICP-40	ICP-40	ICP-40	ICP-40
20	<4	7	3	75	8	<5

Sr ppm	Ta ppm	Th ppm	U ppm	V ppm	Y ppm	Yb ppm
ICP-40	ICP-40	ICP-40	ICP-40	ICP-40	ICP-40	ICP-40
180	<40	<4	<100	78	5	<1

Zn ppm	Ag ppm	As ppm	Au ppm	Bi ppm	Cd ppm	Cu ppm
ICP-40	ICP-10	ICP-10	ICP-10	ICP-10	ICP-10	ICP-10
190	0.91	<1	0.29	<1	<0.05	89

Mo ppm	Pb ppm	Sb ppm	Zn ppm	Au ppm
ICP-10	ICP-10	ICP-10	ICP-10	GF-AAS
4.6	21	<1	130	0.6

Table 7. Mineralogy of salt and precipitate samples collected at the Holden mine, Chelan County, Washington.

Sample	Major Minerals	Minor Minerals
4chc359A	pickeringite gypsum quartz alunogen	kaolinite chlorite amphibole
4chc363A	pickeringite hexahydrite gypsum quartz rozenite siderotil alunogen	kaolinite chlorite amphibole
4chc363B	pickeringite hexahydrite gypsum quartz rozenite siderotil alunogen	kaolinite chlorite amphibole
4chc364P	albite quartz amphibole chlorite	mica
4chc365P	albite quartz amphibole chlorite	mica
4chc366A	pickeringite hexahydrite gypsum	quartz feldspar amphibole chlorite alunogen
4chc366B	albite quartz amphibole chlorite	mica gypsum anhydrite
4chc359B	Amorphous	
4chc362P	Amorphous	

Table 8. Limits of determination for the specrographic analysis of stream sediment samples based on a 10-mg sample. (The spectrographic limits of determination for heavy-mineral concentrate samples are based on a 5-mg sample, and are therefor two reporting intervals higher than the limits given for stream sediments)

Element	Lower determination limit	Upper determination limit
	Percent	
Calcium (Ca)	0.05	20
Iron (Fe)	0.05	20
Magnesium (Mg)	0.02	10
Sodium (Na)	0.2	5
Phosphorous (P)	0.2	10
Titanium (Ti)	0.002	1
	Parts per million	
Silver (Ag)	0.5	5,000
Arsenic (As)	200	10,000
Gold (Au)	10	500
Boron (B)	10	2,000
Barium (Ba)	20	5,000
Beryllium (Be)	1	1,000
Bismuth (Bi)	10	1,000
Cadmium (Cd)	20	500
Cobalt (Co)	10	2,000
Chromium (Cr)	10	5,000
Copper (Cu)	5	20,000
Gallium (Ga)	5	500
Germanium (Ge)	10	100
Lanthanum (La)	50	1,000
Manganese (Mn)	10	5,000
Molybdenum (Mo)	5	2,000
Niobium (Nb)	20	2,000
Nickel (Ni)	5	5,000
Lead (Pb)	10	20,000
Antimony (Sb)	100	10,000
Scandium (Sc)	5	100
Tin (Sn)	10	1,000
Strontium (Sr)	100	5,000
Thorium (Th)	100	2,000
Vanadium (V)	10	10,000
Tungsten (W)	20	10,000
Yttrium (Y)	10	2,000
Zinc (Zn)	200	10,000
Zirconium (Zr)	10	1,000
Palladium (Pd)*	5	1,000
Platinum (Pt)*	20	1,000

* Only determined in heavy-mineral concentrate samples

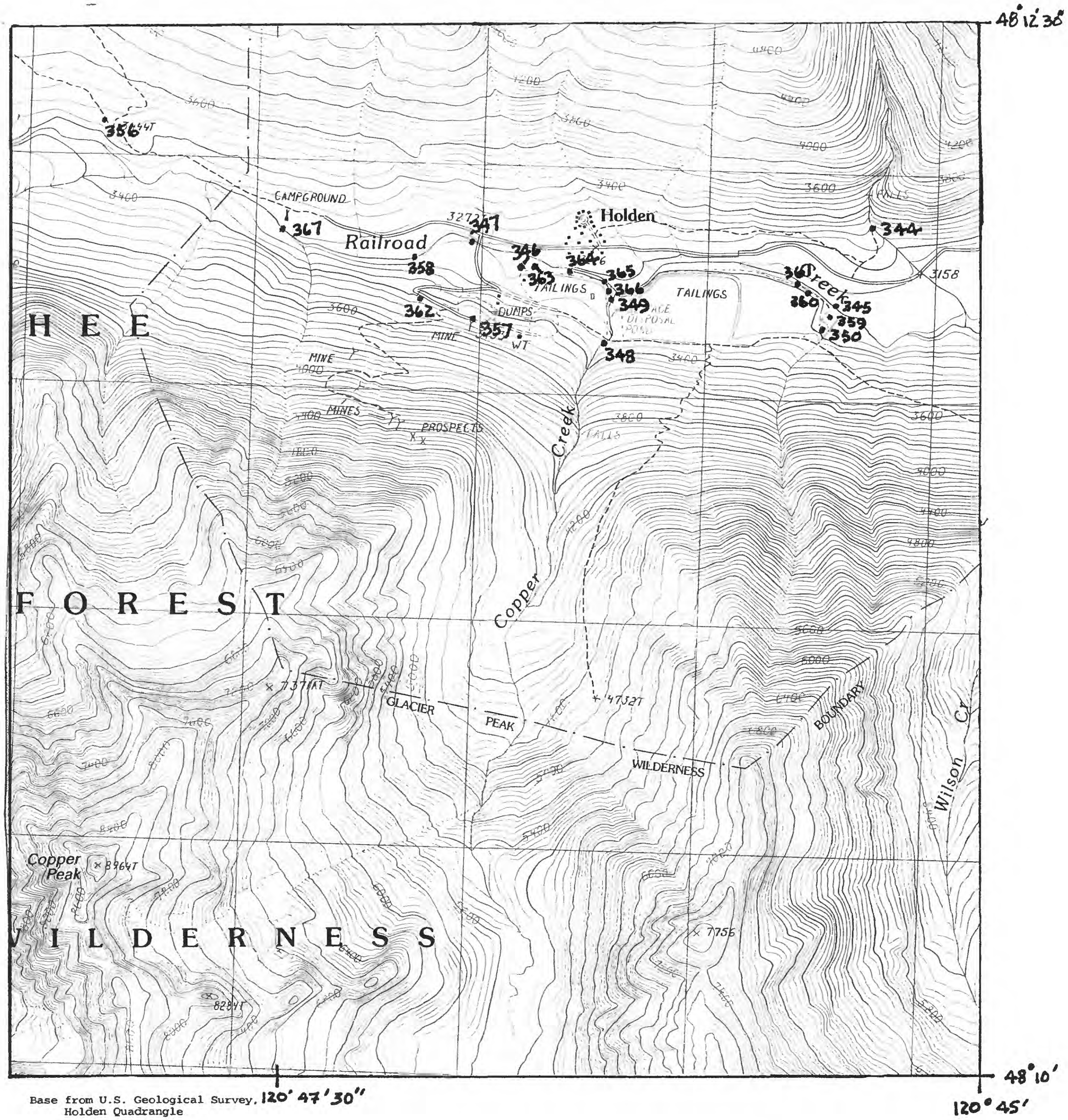
Table 9. Limits of determination for the analysis of geologic material by the 40-element inductively coupled plasma-atomic emission spectrometry (ICP-AES) method.

ELement	Lower determination limit	Upper determination limit
	Percent	
Aluminum (Al)	0.005	50
Calcium (Ca)	0.005	50
Iron (Fe)	0.02	25
Potassium (K)	0.01	50
Magnesium (Mg)	0.005	5
Sodium (Na)	0.006	50
Phosphorous (P)	0.005	50
Titantium (Ti)	0.005	25
	Parts per million	
Silver (Ag)	2	10,000
Arsenic (As)	10	50,000
Gold (Au)	8	50,000
Barium (Ba)	1	35,000
Beryllium (Be)	1	5,000
Bismuth (Bi)	10	50,000
Cadmium (Cd)	2	25,000
Cerium (Ce)	5	50,000
Cobalt (Co)	2	25,000
Chromium (Cr)	2	50,000
Copper (Cu)	2	15,000
Europium (Eu)	2	5,000
Gallium (Ga)	4	50,000
Holmium (Ho)	4	5,000
Lanthanum (La)	2	50,000
Lithium (Li)	2	50,000
Manganese (Mn)	4	50,000
Molybdenum (Mo)	2	50,000
Niobium (Nb)	4	50,000
Neodymium (Nd)	9	50,000
Nickel (Ni)	3	50,000
Lead (Pb)	4	50,000
Scandium (Sc)	2	50,000
Tin (Sn)	5	50,000
Strontium (Sr)	2	15,000
Tantalum (Ta)	40	50,000
Thorium (Th)	6	50,000
Uranium (U)	100	100,000
Vanadium (V)	2	30,000
Yttrium (Y)	2	25,000
Ytterbium (Yb)	1	5,000
Zinc (Zn)	2	15,000

Table 10. Limits of determination for the analysis of geologic material by the 10-element inductively coupled plasma-atomic emission spectrometry (ICP-AES) method.

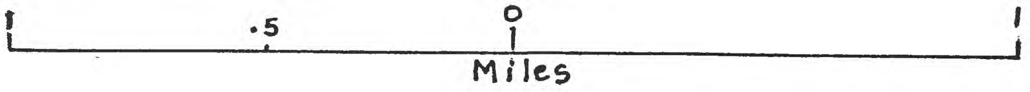
Element	Lower determination limit	Upper determination limit	Element	Lower determination limit	Upper determination limit
Silver (Ag)	0.07	400 ppm	Copper (Cu)	0.05	500 ppm
Arsenic (As)	1	6,000 ppm	Molybdenum (Mo)	0.01	900 ppm
Gold (Au)	0.1	2,000 ppm	Lead (Pb)	1	6,000 ppm
Bismuth (Bi)	1	6,000 ppm	Antimony (Sb)	1	6,000 ppm
Cadmium (Cd)	0.05	500 ppm	Zinc (Zn)	0.05	500 ppm

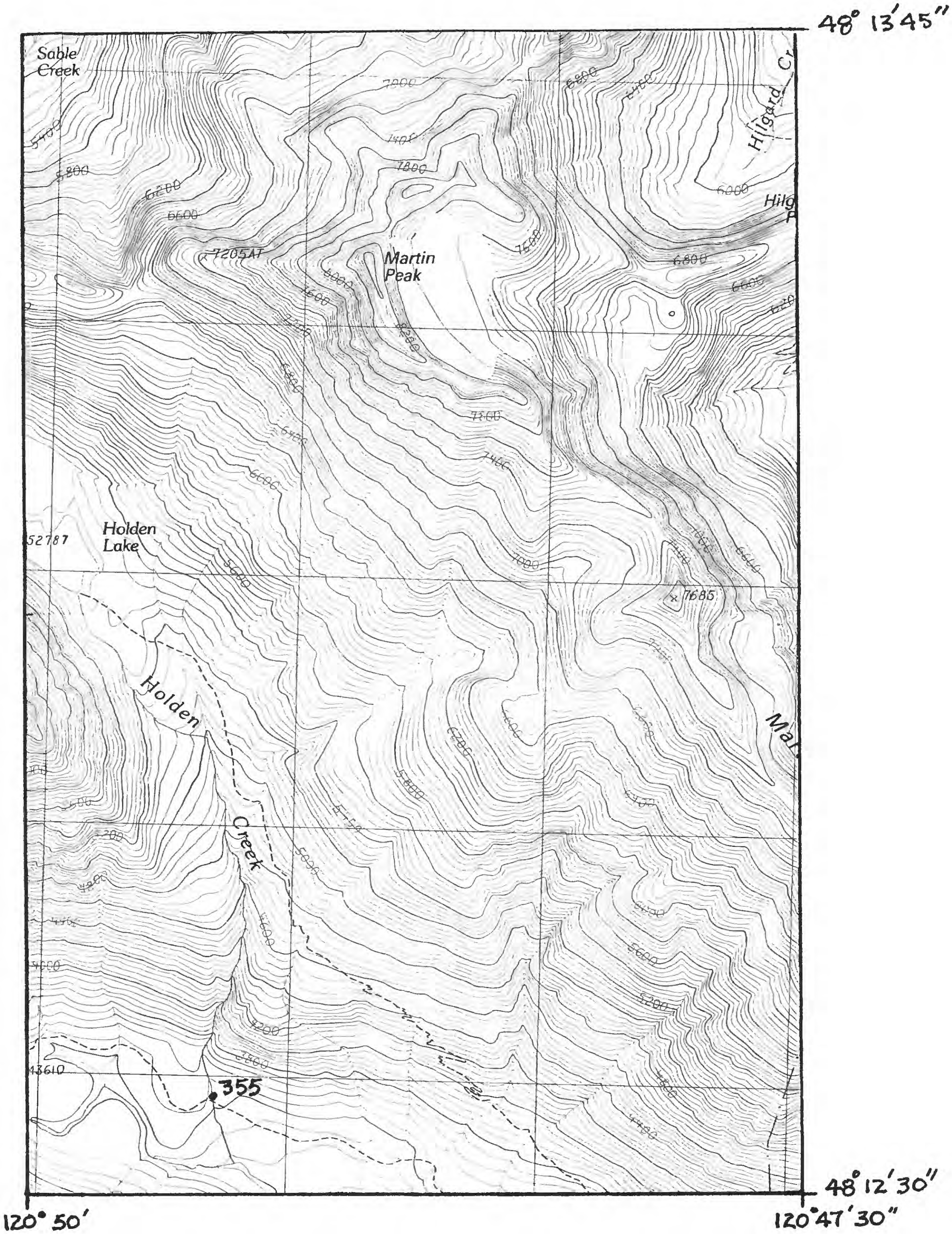
**Detection limits and ranges will vary according to dilution factors.



Base from U.S. Geological Survey, Holden Quadrangle

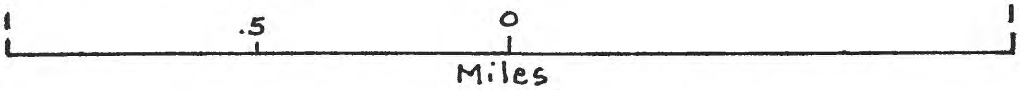
Figure 2. Localities of samples collected in the Holden quadrangle, Chelan County, Washington.

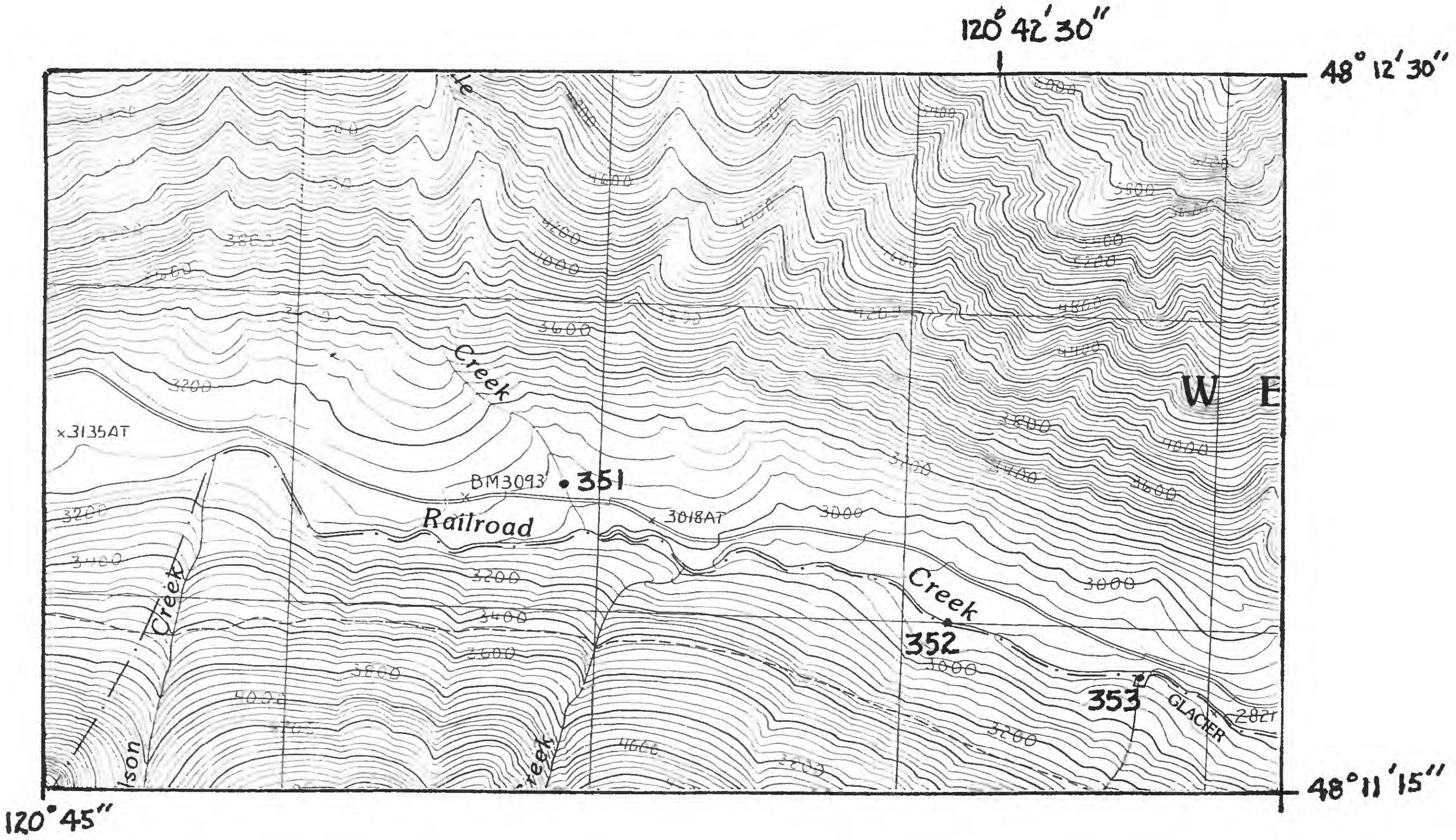




Base from U.S. Geological Survey,
Holden Quadrangle

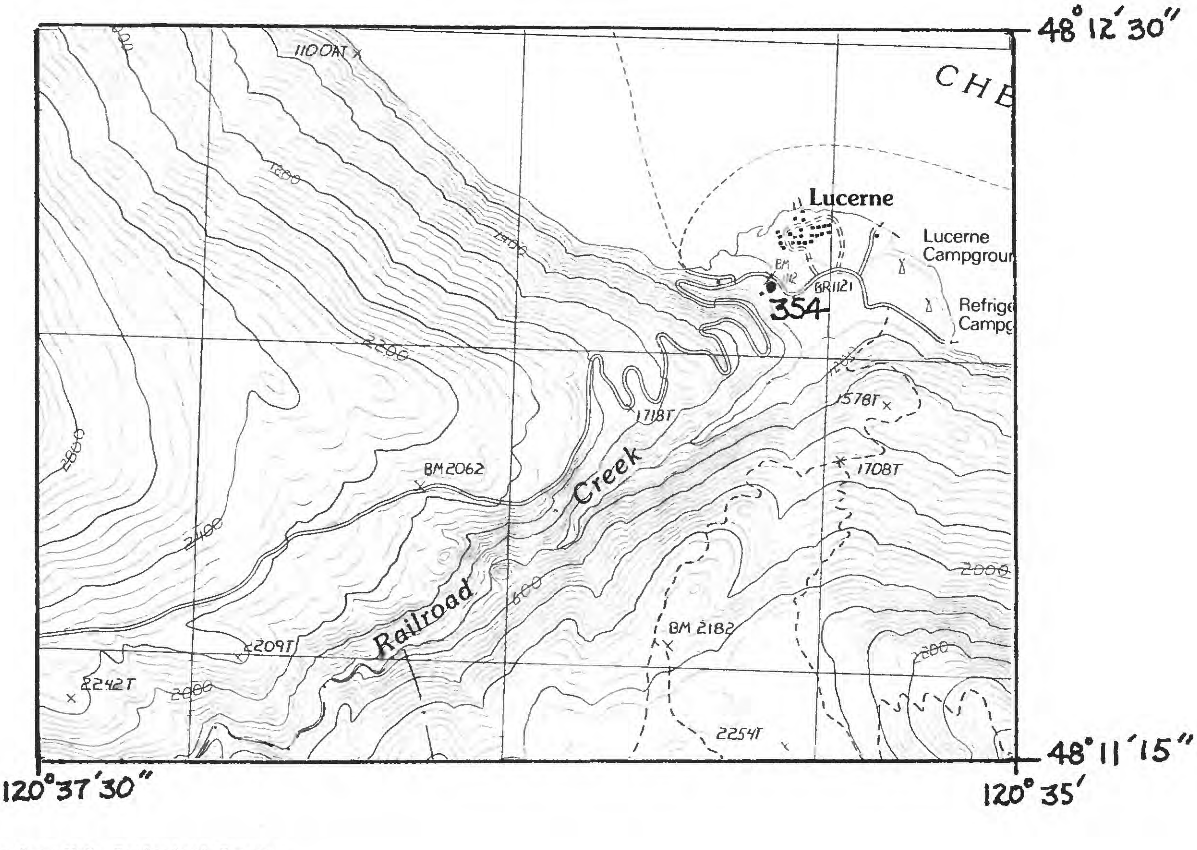
Figure 3. Locality of geochemical sample collected in the Holden quadrangle, Chelan County, Washington.





Base from U.S. Geological Survey, Pinnacle Mountain Quadrangle

Figure 4. Localitities of samples collected in the Pinnacle Mountain quadrangle, Chelan County, Washington.



Base from U.S. Geological Survey,
Lucerne Quadrangle

Figure 5. Locality of geochemical sample collected in the Lucerne quadrangle, Chelan County, Washington.