

U.S. DEPARTMENT OF THE INTERIOR
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**Geochemical data for stream-sediment, heavy-mineral-concentrate, and rock samples
collected from the Fortyseven Creek gold-arsenic-antimony-tungsten prospect,
southwestern Alaska**

By

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INTRODUCTION

In the summer of 1991, we conducted a reconnaissance geochemical survey around the Fortyseven Creek Au-As-Sb-W prospect that is located in the southwestern part of the Sleetmute quadrangle. At that time, this project was a small part of a more comprehensive Alaska Mineral Resource Assessment Program (AMRAP) study of the Sleetmute quadrangle. AMRAP studies were conducted by the U.S. Geological Survey (USGS) to fulfill requirements of the Alaska National Interests Lands Conservation Act (Public Law 96-487, 1980) to survey certain federal lands to determine their mineral potential. Although AMRAP is no longer in operation, this study represents a small topical study that was conducted during the Sleetmute quadrangle AMRAP study. The objective of the Fortyseven Creek work was to characterize the geochemistry of samples collected downstream from the Fortyseven Creek prospect, as well as mineralized and altered rock samples collected from the prospect. In this report, we describe the samples collected in 1991, the methods used for the analysis of the samples, and the geochemical data for these samples. The data in this report are also available in digital form on computer diskette in Gray and others (1999). An interpretation of these data appears in Gray and others (1998).

SITE DESCRIPTION AND HISTORY

The Fortyseven Creek Au-As-Sb-W prospect is located about 95 km southeast of Aniak, on the ridge crest at the headwaters of Fortyseven Creek, a tributary of the Holitna River (fig. 1). This lode and an associated gold placer mine on Fortyseven Creek about 3 km downstream from the prospect were discovered in 1947 by Russell Schaeffer. The lode was first described by Cady and others (1955) as a quartz-scheelite-gold-bearing shear zone cutting highly silicified graywacke and shale of the Kuskokwim Group. Additional exploration and geologic mapping of the Fortyseven Creek area was conducted by Hawley (1989), who described quartz veins cutting silicified sedimentary rock hornfels of the Kuskokwim Group; granite porphyry intrusions also cut the sedimentary rocks in this area. Hawley (1989) also found minor amounts of arsenopyrite, scheelite, stibnite, gold, pyrite, wolframite, jamesonite, and argentite in the veins, with locally abundant sericite (hydrothermal muscovite); these veins were traceable laterally for greater than 1,000 m. Some mineralized samples contain greater than 34 ppm Au (1 oz/t) (Hawley, 1989). The vein has not been mined. However, between 1948-1954, about 28 kg of gold (891 oz) and about 1,900 kg (5000 lbs) of scheelite, containing 67-77 percent WO_3 , were recovered by Schaeffer from the placer mine on Fortyseven Creek downstream from the lode (Hawley, 1989).

Several companies conducted exploration of the Fortyseven Creek area in the 1970's and 1980's including Homestake, Amax, American Copper and Nickel, and Anaconda (Hawley, 1989). More recently, from 1991-1994, Nevada Star Resources conducted exploration of the area that included minor prospect trenching, an extensive soil geochemical survey, and exploration drilling (Maynard, 1995). Nevada Star collected over 200 soil samples along the ridges at the headwaters of Fortyseven Creek and found highly elevated concentrations of Au (as much as 1.3 ppm), As (as much as 8,230 ppm), Bi (as much as 100 ppm), Cu (as much as 322 ppm), Sb (as much as 106 ppm), and W (as much as 510 ppm) in these soils. Nevada Star used soil anomalies of Au, As, and Bi to delineate several target areas for three exploration drill holes. Drilling was difficult due to circulation loss and hole caving problems. Consequently, only one drill hole penetrated significant mineralized rock about 44-105 m (145-345 ft) below the surface that contained as much as 1.2 ppm Au (Maynard, 1995).

The Fortyseven Creek prospect has geologic and geochemical characteristics similar to other gold deposits in southwestern Alaska such as the Au-As-W Golden Horn mine near Flat, and the Au-As-Sb Donlin Creek deposit (fig. 1). There is presently considerable exploration for such gold deposits in southwestern Alaska, but these deposits have not been well studied.

GEOLOGY

Rocks in the Fortyseven Creek area consist mostly of interbedded graywacke and siltstone of the Cretaceous Kuskokwim Group that are cut by small granite porphyry intrusions of probable Late Cretaceous or early Tertiary age (Cady and others, 1955; Hawley, 1989). The Kuskokwim Group is a sequence of flysch representing turbidite fan, foreslope, shallow-marine, and shelf facies deposited into an elongate, northeast trending, fault-controlled Cretaceous basin (Decker and Hoare, 1982; Bundtzen and Gilbert, 1983). Fossil ages for the Kuskokwim Group range from Albian to Campanian (Cady and others, 1955; Hoare and Coonrad, 1959; Box and Murphy, 1987; Box and Elder, 1992; Miller and Bundtzen, 1994). Granite porphyry intrusions in the Fortyseven Creek area are similar to those found elsewhere in southwestern Alaska. These intrusions are generally

peraluminous in composition, with Al_2O_3 exceeding $\text{Na}_2\text{O} + \text{K}_2\text{O} + \text{CaO}$, and locally contain igneous garnet (Bundtzen and Swanson, 1984; Moll-Stalcup, 1994). The granite porphyry near Fortyseven Creek has not been dated, but similar rocks in southwestern Alaska are Late Cretaceous and early Tertiary (about 72 to 61 Ma), based on K-Ar determinations (Reifenstuhl and others, 1984; Robinson and Decker, 1986; Decker and others, 1986; 1995; Miller and Bundtzen, 1994; Bundtzen and Miller, 1997). Gray and others (1998) obtained a $^{40}\text{Ar}/^{39}\text{Ar}$ plateau age of 67.1 ± 0.1 Ma for hydrothermal sericite separated from a sample of mineralized quartz vein from the Fortyseven Creek prospect. This age represents the best estimate of the timing of mineralization at Fortyseven Creek and is coeval with Late Cretaceous-early Tertiary granite porphyry intrusions found throughout southwestern Alaska. Late Cretaceous and early Tertiary magmatism is interpreted to be related to a broad subduction arc (Moll-Stalcup, 1994; Szumigala, 1993). Granite porphyry intrusions are important in southwestern Alaska because they show a close spatial and temporal association with Au-As-Sb-W and Hg-Sb veins (Cady and others, 1955; Bundtzen and Miller, 1997; Gray and others, 1997).

METHODS OF STUDY

Sample Media

In this study, stream-sediment and heavy-mineral-concentrate samples were collected to provide information about the rocks eroded from the drainage basin upstream from each sample site (fig. 2). Analyses of stream-sediment samples are representative of the geochemistry of rocks contained within the drainage basins. Heavy-mineral-concentrate samples provide information about higher density minerals that are eroded from rocks in the drainage basins. The heavy-mineral-concentrate collection procedure selectively concentrates the minerals with high specific gravity, many of which may be related to mineral deposits. Collection of heavy-mineral-concentrate samples facilitates concentration of some elements that are not easily detected in stream-sediment samples. Altered and mineralized rock samples were collected from the Fortyseven Creek prospect to characterize the geochemistry of this type of mineral deposit.

The stream-sediment material collected consisted of alluvium (bed sediment) in the active stream channel. Where possible, samples were composited by collecting sediment from several localities in the active channel. The stream sediment was screened to minus-10 mesh (2 mm) and collected in a stainless steel gold pan. About 2 kg of sediment was taken from the pan and saved as the stream-sediment sample.

Heavy-mineral-concentrate samples were collected from the same active alluvium (bed sediment) as the stream-sediment samples. At each sample site, the gold pan was filled with stream sediment screened to minus-10 mesh and panned until most of the less dense minerals, organic materials, and clays were removed. This resulting panned-concentrate sample was later processed in the laboratory as described below to obtain a heavy-mineral-concentrate sample.

Sample Preparation

In the laboratory, the stream-sediment samples were air dried, sieved to minus-80 mesh (0.18 mm), pulverized to less than 100 mesh (0.15 mm), and chemically analyzed by the methods described in the following section. The heavy-mineral-concentrate samples were sieved to minus-35 mesh (0.50 mm), and then separated using bromoform (specific gravity 2.85) to remove any remaining lighter minerals, primarily quartz and feldspar. The resultant heavy-mineral-concentrate samples were then separated into magnetic, paramagnetic, and nonmagnetic fractions using a modified Frantz Isodynamic Separator. The most magnetic material was removed at a setting of 0.25 ampere and contained mostly magnetite. The paramagnetic fraction was removed at 1.75 ampere and consisted largely of ferromagnesian silicates and iron oxides. The nonmagnetic fraction of the heavy-mineral-concentrate samples contained sulfide minerals, gold, and some nonmagnetic oxides and silicates; this was the only fraction chemically analyzed. Rock samples were crushed, ground, pulverized to less than 100 mesh, and analyzed by the analytical methods described below.

ANALYTICAL METHODS

Semiquantitative Spectrography (SQS)

The rock, minus-80-mesh stream-sediment, and minus-35-mesh nonmagnetic-heavy-mineral-concentrate samples were analyzed by semiquantitative, direct-current arc emission spectrography (SQS) using a technique

adapted from Grimes and Marranzino (1968). Spectrographic results were determined by visually comparing spectra derived from the sample against spectra obtained from laboratory reference standards made from pure oxides and carbonates. Standard concentrations are geometrically spaced over any given order of magnitude as follows: 100, 50, 20, 10, etc. Samples whose concentrations were estimated to fall between those values were assigned values of 70, 30, 15, etc. The precision of this analytical technique is approximately \pm one reporting interval at the 83 percent confidence level and \pm two reporting intervals at the 96 percent confidence level (Motooka and Grimes, 1976). Values determined for the major elements Fe, Mg, Ca, Na, Ti, and P are given in weight percent; all other values are in parts per million (micrograms/gram). In addition, Pd and Pt were determined in the heavy-mineral-concentrate samples by emission spectrography. The elements determined by emission spectrography and their limits of determination are listed in table 1. Data for stream-sediment samples determined by this technique are listed in table 3; the heavy-mineral-concentrate data are listed in table 4, and the rock data are listed in table 5.

Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES)

Concentrations of Ag, As, Au, Bi, Cd, Cu, Mo, Pb, Sb, and Zn were determined in the rock and stream-sediment samples by inductively coupled plasma-atomic emission spectroscopy (ICP-AES) using the procedure developed by Motooka (1996). The sediments were decomposed with concentrated hydrochloric acid and hydrogen peroxide in a hot-water bath. The metals were extracted in diisobutyl ketone (DIBK) in the presence of ascorbic acid and potassium iodide. The DIBK phase was then aspirated directly into the plasma and element concentrations were determined simultaneously with a multichannel ICP instrument.

Atomic Absorption Spectrophotometry (AAS)

Concentrations of Au, Te, and Tl in the rock and stream-sediment samples were determined by an atomic absorption spectrophotometry (AAS) technique adapted from Hubert and Chao (1985). The samples were digested using a series of hydrogen peroxide, hydrofluoric acid, aqua-regia, and hydrobromic acid-bromine solutions. Gold, Te, and Tl were separated and concentrated by extraction into methyl isobutyl ketone and determined by flame atomic absorption spectrophotometry. Concentrations for Au in the range of 0.002 to 0.050 ppm were determined by graphite furnace atomic absorption spectrophotometry on samples that were shown to be less than 0.050 ppm by the flame atomic absorption spectrophotometry technique. The graphite furnace atomic absorption spectrophotometry technique for Au was adapted from Meier (1980).

Mercury was measured in the rock and stream-sediment samples using a modified version of the cold-vapor atomic AAS technique (Kennedy and Crock, 1987). The samples were decomposed with nitric acid and sodium dichromate. Mercury (II) was reduced to elemental mercury with hydroxylamine hydrochloride/sodium chloride and stannous chloride in a continuous flow system releasing the vapor into a quartz cell of an atomic absorption spectrophotometer where the concentration of mercury was determined.

The rock and stream-sediment samples were analyzed for Se using continuous-flow hydride generation AAS (Sanzolone and Chao, 1987). In this method, the stream-sediment samples were digested using nitric, perchloric, and hydrofluoric acids; hydrochloric acid was added to reduce Se (VI) to Se (IV), which is necessary for the accurate determination of Se using hydride generation AAS. A mixture of hydrochloric acid, sodium borohydride, and sodium hydroxide was added to produce selenium hydride, which is then stripped and transported with inert gas to the atomizer of the atomic absorption spectrophotometer where Se concentration was determined.

Visible Spectrophotometry (VS)

Tungsten was determined in the rocks and stream-sediment samples by a visible spectrophotometric (VS) method by decomposing the samples with nitric, hydrofluoric, and hydrochloric acids (Welsch, 1983). Stannous chloride and dithiol solution was added to reduce the W, forming the blue tungsten-dithiol complex, which was then extracted into heptane. The color intensity of the tungsten-dithiol complex is proportional to the concentration of W in the sample. Tungsten concentrations were determined using a visible absorption spectrophotometer.

Selective Ion Electrode Analysis (SIE)

Fluoride concentrations were determined in the rock and stream-sediment samples by selective ion electrode (SIE) analysis using a method modified from Bodkin (1977). Samples were fused with lithium

metaborate, and then dissolved in nitric acid. A complexing buffer was added, and concentrations were determined using a fluoride-selective ion electrode.

X-Ray Fluorescence (XRF)

The rock samples were also analyzed for major element oxides by a wavelength dispersive X-ray fluorescence spectroscopy (XRF) method (Taggart and others, 1990). In this procedure the samples were fused with lithium tetraborate and formed into a glass disk. The disks were irradiated with X-rays, and X-ray photons emitted by the elements present in the sample were counted and concentrations determined using calibrated standards. The weight of the sample loss on ignition (LOI) at 925°C was determined gravimetrically. The elements determined by this technique and the concentration range limitations are shown in table 2.

Coulometric Titration (CT)

Concentrations of CO₂ and H₂O were measured in the rock samples. The amount of CO₂ was determined by a coulometric titration (CT) technique following sample digestion with perchloric acid (Jackson and others, 1987). Total water was determined by coulometry using a titration method after fusion with a PbO-PbCrO₄-CaCO₃ flux at 900°C (Norton and Papp, 1990). The amount of moisture (H₂O⁻) was determined by weight loss after heating the samples at 110°C. The amount of H₂O⁺ was determined by the calculation: [H₂O_{Total} - H₂O⁻ = H₂O⁺]. Lower limits of determination for CO₂ and H₂O are shown in table 2.

DIGITAL DATA

The geochemical data in this report are also part of the USGS National Geochemical Database in Denver that contains both descriptive geological information and analytical data. This report may also be obtained on the USGS web site at: greenwood.cr.usgs.gov/pub/open-file-reports/ofr-99-0584/.

DESCRIPTION OF DATA TABLES

Table 3 contains the geochemical data for the stream-sediment samples collected during this study; table 4 contain the data for the heavy-mineral-concentrate samples, and table 5 contain the data for the rock samples. Sample site locations are given in latitude and longitude and decimal degrees in the tables, and these sample sites are shown on figure 2. The analytical method for each element shown in tables is abbreviated as a suffix in the column headings. The designation "SQS" indicates semiquantitative emission spectrography, "ICP" indicates inductively coupled plasma-atomic emission spectroscopy, "AAS" indicates atomic absorption spectrophotometry, "VS" indicates visible spectrophotometry, "SIE" indicates selective ion electrode analysis, "XRF" indicates X-ray fluorescence spectroscopy, and "CT" indicates coulometric titration. Discrepancies in analyses for certain elements duplicated by different analytical methods, such as values determined for Au in stream-sediment samples, may be attributable to the particulate nature of minerals that contain Au (i.e., nugget effect), different sample aliquots used, and different extraction procedures. Due to the larger sample aliquot analyzed, the atomic absorption spectrophotometry analysis of Au generally provides more representative results than emission spectrography. For example, a 10-gram sample aliquot is used for the atomic absorption spectrophotometry analysis, whereas a 10-milligram sample aliquot is used in the emission spectrography technique. There is no data for heavy-mineral-concentrate sample 91FS02C because there was insufficient material for geochemical analysis following preparation in the laboratory.

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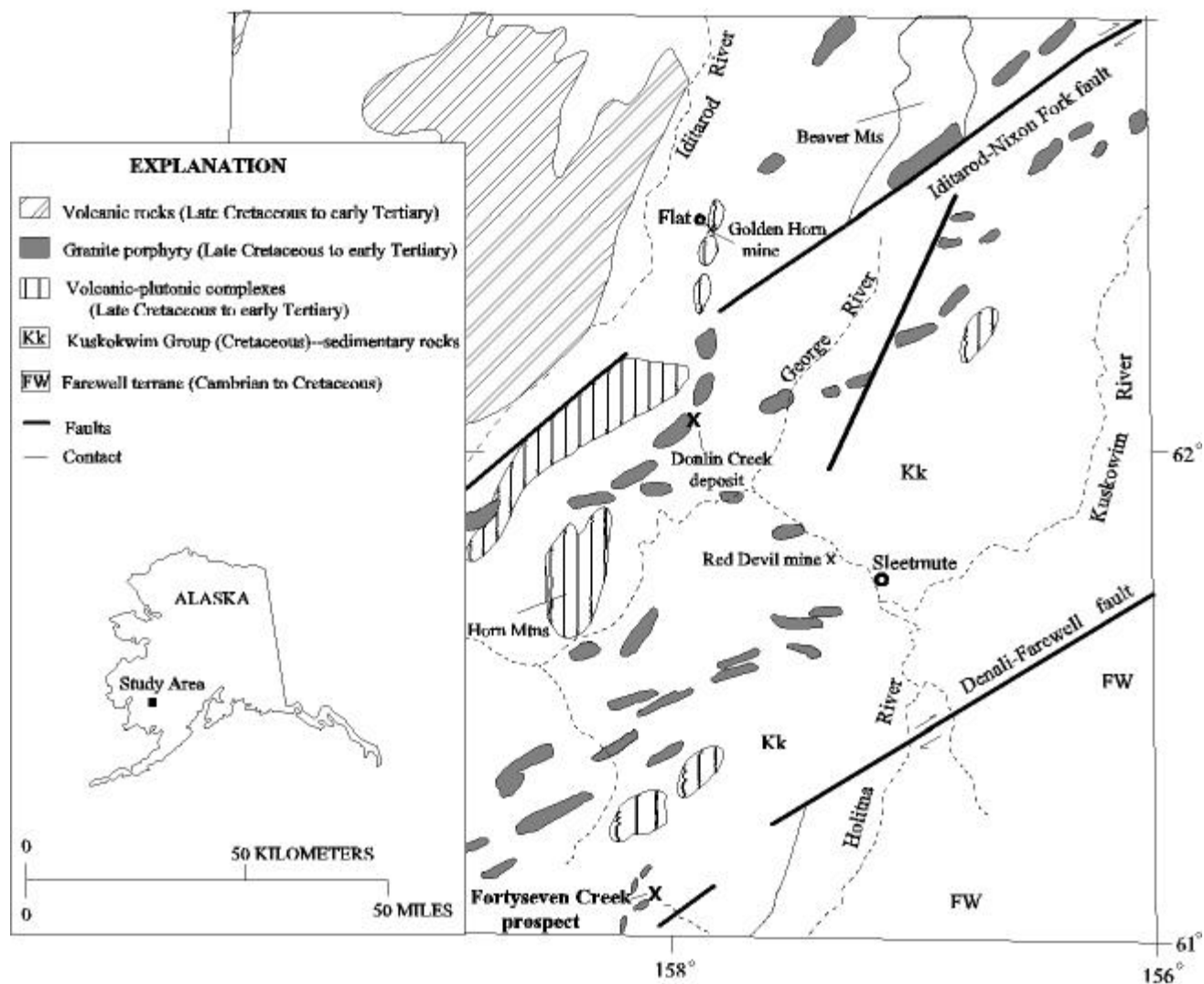


Figure 1. Map showing the location of the Fortyseven Creek prospect in southwestern Alaska. Geology generalized from Cady and others (1955), Hoare and Coonrad (1959), Decker and others (1984; 1994; 1995), Miller and Bundtzen (1994), and Bundtzen and Miller (1997).

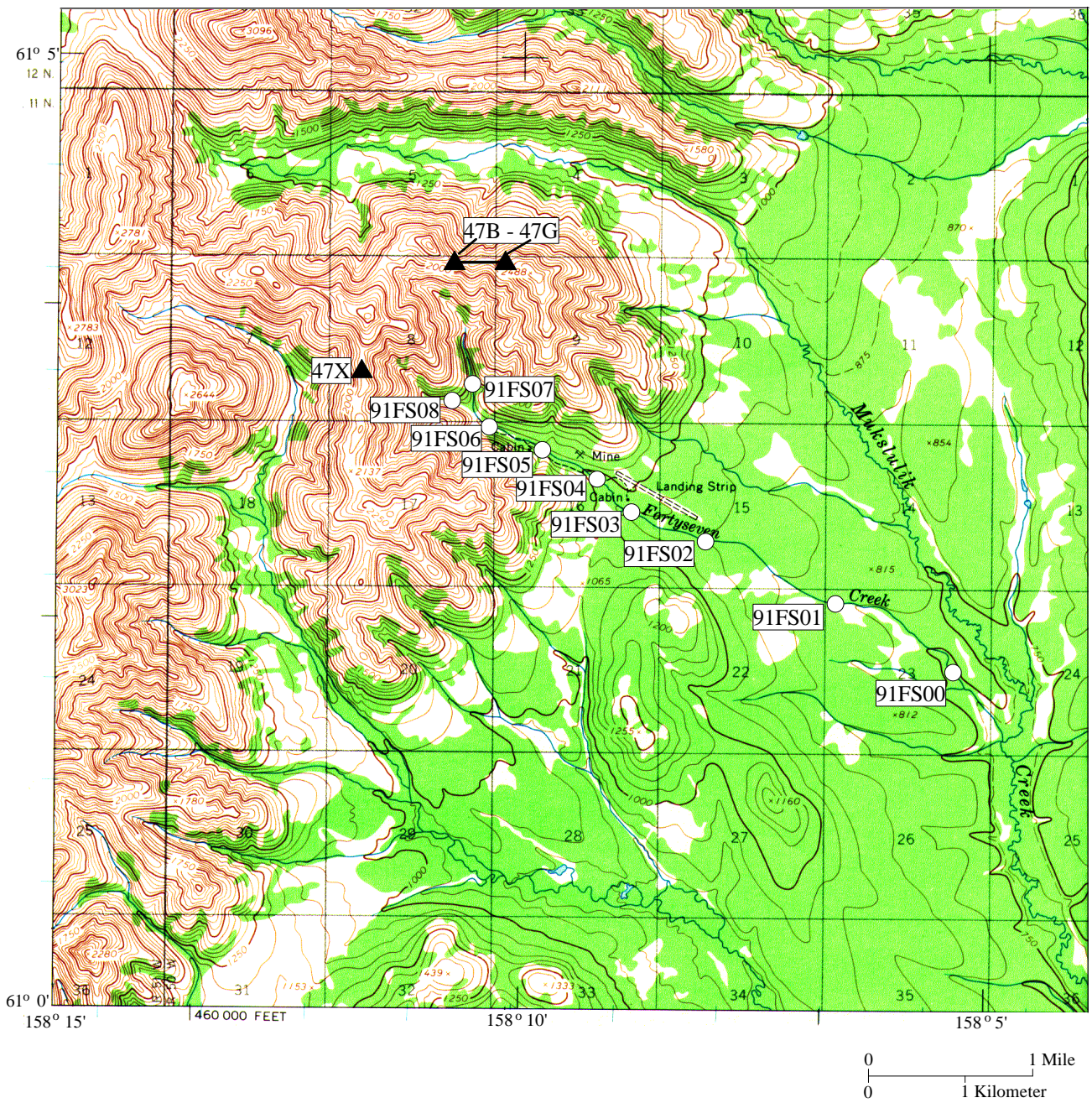


Figure 2. Location of samples collected in the Fortyseven Creek study. Circles indicate stream-sediment and heavy-mineral-concentrate sites and triangles indicate rock sample sites.

Table 1. Limits of determination for the spectrographic 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 weight, and are therefore two reporting intervals higher than the limits given for stream sediments]

Elements	Lower determination limit	Upper determination limit
	Percent	
Iron (Fe)	0.05	20
Magnesium (Mg)	0.02	10
Calcium (Ca)	0.05	20
Sodium (Na)	0.2	5
Titanium (Ti)	0.002	1
Phosphorous (P)	0.2	10
	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	100
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

*Determined in heavy-mineral-concentrate samples only.

Table 2. Limits of determination for the analysis of stream-sediment and rock samples by several analytical techniques.

[ICP-AES, inductively coupled plasma-atomic emission spectroscopy; AA, atomic absorption spectrophotometry; VS, visible spectrophotometry; SIE, selective ion electrode analysis; CT, coulometric titration, and XRF, X-Ray fluorescence spectroscopy;].

Element	Analytical Method	Lower limit	Upper limit
Silver (Ag)	ICP-AES	0.045 ppm	1,500 ppm
Arsenic (As)	ICP-AES	0.6 ppm	3,000 ppm
Gold (Au)	ICP-AES	0.15 ppm	2,400 ppm
Bismuth (Bi)	ICP-AES	0.6 ppm	1,500 ppm
Cadmium (Cd)	ICP-AES	0.03 ppm	500 ppm
Copper (Cu)	ICP-AES	0.03 ppm	1,200 ppm
Molybdenum (Mo)	ICP-AES	0.09 ppm	1,500 ppm
Lead (Pb)	ICP-AES	0.6 ppm	12,000 ppm
Antimony (Sb)	ICP-AES	0.6 ppm	800 ppm
Zinc (Zn)	ICP-AES	0.03 ppm	500 ppm
Tellurium (Te)	AAS	0.050 ppm	
Thallium (Tl)	AAS	0.050 ppm	
Gold (Au)	AAS	0.002 ppm	
Mercury (Hg)	AAS	0.02 ppm	
Selenium (Se)	AAS	0.1 ppm	
Tungsten (W)	VS	1.0 ppm	
Fluoride (F)	SIE	200 ppm	
Tungsten (W)	ICP-MS	1.0 ppm	
Carbon dioxide (CO ₂)	CT	0.01 %	
Water (H ₂ O)	CT	0.1 %	
Calcium (CaO)	XRF	0.02 %	
Iron (Fe _(T) O ₃)	XRF	0.04 %	
Magnesium (MgO)	XRF	0.1 %	
Sodium (Na ₂ O)	XRF	0.15 %	
Phosphorous (P ₂ O ₅)	XRF	0.05 %	
Titanium (TiO ₂)	XRF	0.02 %	
Manganese (MnO)	XRF	0.01 %	
Silica (SiO ₂)	XRF	0.1 %	
Alumina (Al ₂ O ₃)	XRF	0.1 %	
Potassium (K ₂ O)	XRF	0.02 %	