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U.S. GEOLOGICAL SURVEY

Geochemical data for selected rock samples from the Absaroka-Beartooth study area, Custer and Gallatin National Forests, Montana

By

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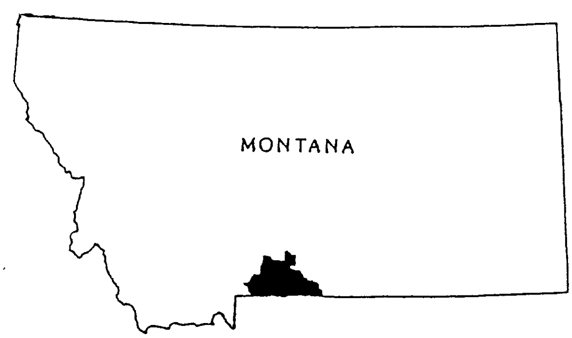

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code.

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INTRODUCTION

The Absaroka-Beartooth study area (ABSA) is a parcel of approximately 1.4 million acres of National Forest land that includes southeastern parts of the Gallatin National Forest and western parts of the Custer National Forest in south-central Montana. The ABSA is adjacent to the northern boundary of Yellowstone National Park (fig. 1) and covers parts of Park, Sweet Grass, Stillwater, and Carbon Counties. A mineral resource assessment of the Absaroka-Beartooth study area was conducted by the U.S. Geological Survey (Hammarstrom and others, 1993). Hydrothermally altered and mineralized rock samples were collected by Hammarstrom during field investigations of the Absaroka-Beartooth study area in 1991 with assistance from U.S. Geological Survey colleagues Jim Elliott, Brad Van Gosen, Steve Harlan, and Andy West. This geochemical study was conducted to determine the metal associations present in different parts of the study area by analyzing for a wide variety of elements in selected samples which represent various types of altered or mineralized rock. These data can be used to (1) aid recognition of different types of mineral deposits, (2) place constraints on interpretation of stream sediment geochemical data, (3) supplement geochemical data from previous studies, and (4) identify geochemical associations.

Interested readers are referred to the mineral resource assessment of the Absaroka-Beartooth study area for details on the geology (Elliott and others, 1993), stream sediment geochemistry (Lee and Carlson, 1993), and mineral resources (Hammarstrom and others, 1993) of the areas sampled for this study. Brad Van Gosen and Bob Carlson kindly reviewed and improved this report.

DESCRIPTION OF SAMPLES

Samples were collected from six areas within the Absaroka-Beartooth study area (fig. 1), including organized mining districts (Emigrant, Independence, and New World) and mineralized areas (Mill Creek, Goose Lake, and the Sliderock Mountain area). Four of the areas sampled (Emigrant, Independence, New World, and Sliderock Mountain) represent the deeply eroded roots of stratovolcano complexes. The Sliderock Mountain volcano and associated gold mineralization are Late Cretaceous in age (Du Bray and Harlan, 1993). The other volcanic complexes form part of the regionally extensive Absaroka-Gallatin volcanic province of Eocene age (Chadwick, 1970). All of these intrusive centers have identified mineral resources and(or) undiscovered mineral resource potential for porphyry copper-gold-molybdenum and related types of mineral deposits, such as skarns and polymetallic veins.

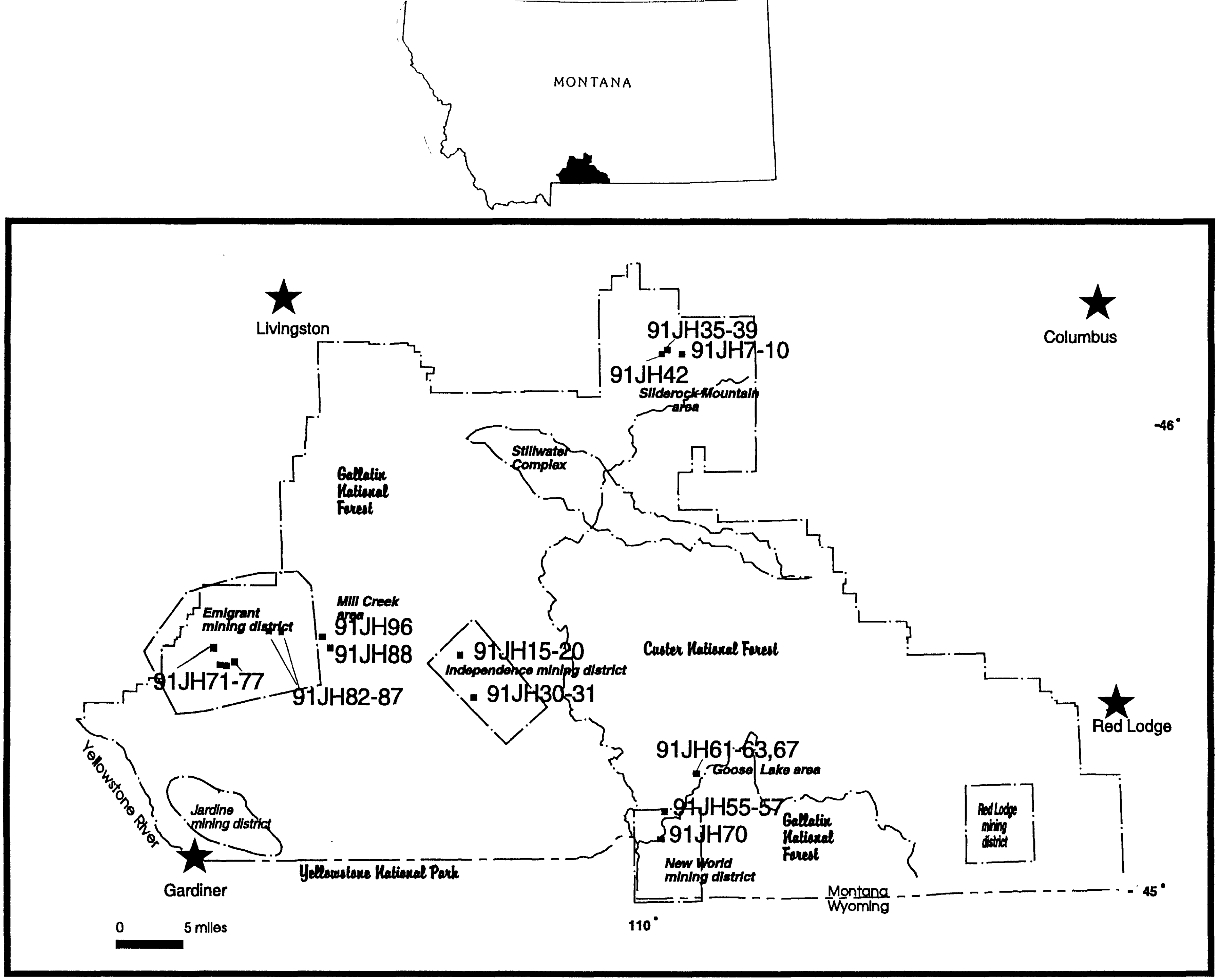

Figure 1. Map of the Absaroka-Beartooth study area showing mining districts, mineralized areas, and sample locations for this study.

Two areas in the ABSA were sampled to confirm previous reports of platinum group elements in rocks not associated with the Stillwater Complex (fig. 1), an Archean layered mafic intrusion that contains significant resources of copper, nickel, chromium, and platinum-group elements. The two areas sampled are: (1) a Late Cretaceous syenite complex in the Goose Lake area and (2) a mineralized shear zone in Precambrian diorite in the Mill Creek area. No samples from the Stillwater Complex are included in this report. The geology, geochemistry, and mineral resources of the Stillwater Complex are described in detail by Zientek (1993a).

Many of the rocks sampled for this study represent relatively minor mineral occurrences in mining districts where identified resources for historically significant mineral deposits are well-documented by other studies. Few data are available for platinum-group element (PGE) analyses for most parts of the study area away from the Stillwater Complex. Also, much of the data in the exploration literature represents assay data for selected elements; data for elements that can be useful as pathfinders for some deposit types, such as arsenic, bismuth, and cadmium, are seldom reported.

All samples were collected from surface outcrops. Location information (7 1/2 minute topographic quadrangle map, latitude, and longitude) and brief descriptions of each sample are given in table 1. Analytical data for each of the six areas are listed in tables 2 through 8. Multiple samples (indicated as a,b,c, etc. suffixes to sample numbers in tables 2 through 7) were collected at some localities to document local variations in rock type.

ANALYTICAL METHODS

Forty two samples were prepared by the authors and analyzed in the U.S. Geological Survey Branch of Geochemistry laboratories in Denver, CO and Reston, VA. Samples (10 kg or more) were cleaned, crushed, pulverized, and ground to a powder that passed a 200-mesh screen size. All samples were analyzed for forty major and trace elements by inductively coupled plasma atomic emission spectroscopy (ICP-AES) following acid decomposition of the sample (Lichte and others, 1987; Crock and others, 1983). All of the ICP-AES determinations were done in Denver by D.L. Fey and J.M. Motooka. In addition, 1.0 gram sample splits were partially dissolved and a solvent extraction technique was used, prior to ICP-AES analysis, to determine concentrations of silver, arsenic, bismuth, cadmium, copper, molybdenum, lead, antimony, and zinc (Motooka, 1988). The reader should bear in mind that the solvent extraction data represent partial sample dissolution whereas the ICP-AES data reported for other elements represent approximately total sample dissolutions. Gold concentrations were analyzed in the Reston laboratory by H. Smith using graphite furnace atomic absorption spectroscopy (GFAA) following chemical separation (Meier, 1980). This enabled gold analyses at lower limits of detection than can be obtained by the multielement ICP technique. Ten gram sample splits were used for the gold determinations.

Eighteen samples were analyzed for the platinum group elements (platinum, palladium, rhodium, ruthenium, and iridium) utilizing ICP-mass spectrometry (ICP-MS) in the Denver laboratory and procedures developed by Meier and others (1991). Samples were analyzed by J. Bullock and A.L. Meier.

In addition to the multielement ICP-AES analysis, further chemical analyses were performed for sample 91JH96 (table 8), a Tertiary dacite porphyry from the Mill Creek area, for comparison with published geochemical data for rocks of the Absaroka-Gallatin volcanic province (Chadwick, 1970). Analytical techniques used include: wavelength dispersive x-ray fluorescence spectrometry (XRF) for major elements (Taggart and others, 1990), J.S. Mee and D.F Siems, analysts; ion-selective electrode analysis of fluorine and chlorine (Aruscavage, 1990; Kirschenbaum and Doughten, 1990), C.J. Skeen and J.R. Gillison, analysts; coulometric water and CO_2 and potentiometric ferrous iron oxide determinations (Brandt and others, 1990; Norton and Papp, 1990; Papp and others, 1990), J.W. Marinenko, analyst; energy-dispersive x-ray fluorescence analysis of Rb,Sr, Y, Zr, and Nb (King, 1990), J.R. Evans, analyst; and instrumental neutron activation analysis (INAA) for 32 elements including rare earth elements (Baedecker and McKown, 1987), J.N. Grossman, analyst.

DISCUSSION

Sliderock Mountain area (table 2)

The Sliderock Mountain area represents a deeply eroded Upper Cretaceous stratovolcano (DuBray and Harlan, 1993). Gold-bearing quartz veins are present near Gold Hill and exploration by private industry identified a shallow, buried porphyry copper-gold-molybdenum target (Cavanaugh, 1990). Samples analyzed for this study include a sericitically altered diorite of Sliderock Mountain from an area near the Gold Hill mine that contains disseminated pyrite; magnetite- and calcsilicate-rich skarn formed in roof pendants of Mississippian Madison Limestone within the diorite near Fire Ridge; hornfels; and finely laminated calcsilicate rock (skarnoid) adjacent to a sill. $^{40}Ar/^{39}Ar$ isochron ages of 73 to 74 Ma obtained on sericite separated from altered porphyry samples (91JH35 and 91JH36, table 2) establish a Cretaceous age for the hydrothermal alteration (Du Bray and Harlan, 1993).

With the exception of one of the three magnetite-rich skarn samples, gold was detected in all of the samples from the Sliderock Mountain area at concentrations of 0.002 parts per million (ppm) or more. The highest gold value observed is 0.26 ppm for sample 91JH35a, a sericitized quartz-eye porphyry. These gold values are comparable to the values (68 to 204 parts per billion) reported by ECM, Inc. (Cavanaugh, 1990) as anomalous gold detected in shallow exploration drilling on the Gold Hill property. The only sample from the Sliderock Mountain area that contains silver at concentrations above the detection limit (4 ppm) is a gossan near the old Gold Hill mine; this sample also has elevated values of lead and zinc. Copper is present in all samples (4 to 830 ppm); low levels of molybdenum are present (solvent extraction data) in all of the samples. No platinum-group elements were detected in any of the five skarn samples analyzed by ICP-MS.

Independence mining district (table 3)

The Independence mining district is centered around the Independence stock, a Tertiary volcanoplutonic center of the Absaroka-Gallatin volcanic province. The Independence stock lies along a northwest trending belt of intrusive centers that were emplaced along the Cooke City structural sag zone. Elliott and others (1983) described the geology and ore deposits of the district, including the two locations sampled for this study. Most of the historic mining and exploration activity in the district concentrated on lode gold deposits associated with the intrusive center; recent exploration efforts were focused on a porphyry copper-gold-molybdenum target. Moyle and others (1989) sampled the Independence stock area extensively.

Two other types of potential mineral deposits in the Independence mining district - skarn and polymetallic vein prospects - were sampled in our study. Six samples of calcsilicate-, magnetite-, and sulfide-bearing skarn were collected from the Lori Kay prospects on War Eagle Mountain, where intrusion of a Cretaceous granodiorite sill (S. Harlan, oral commun., 1992) metamorphosed Cambrian Meagher Limestone. Two samples of metasedimentary rocks containing stringers and disseminations of sulfide minerals were collected at the 7777 lead-zinc claim on Sheep Creek. The prospect along the creek exposes a mineralized fault at the contact between the Cambrian Flathead Sandstone and Wolsey Shale.

New World (Cooke City) mining district (table 4)

Prospect pits along Precambrian granite contacts with Cambrian Flathead Sandstone in the northwestern part of the New World mining district were sampled, as well as an altered andesite porphyry dike cutting Precambrian granite, and sulfide-rich rocks at the Black Warrior mine, a polymetallic (lead-zinc-silver) vein and replacement deposit in Cambrian carbonate rocks distal to the exposed intrusive centers in the central part of the district. All of these occurrences represent polymetallic (lead-zinc-silver$\pm$gold) mineralization distal to the copper-gold-silver deposits associated with the Cooke City intrusive center Elliott and others, 1992).

Gold is detected in all of the samples in the following concentrations (GFAA data): 0.002 to 0.009 ppm in the Precambrian-Cambrian contact rocks, 0.02 ppm in the altered andesite porphyry dike, and 68 ppm in an ore sample from the Black Warrior mine.

Goose Lake area (table 5)

Goose Lake is located a few kilometers northeast of the New World mining district (fig. 1). The mines and prospects of the Goose lake area are centered around a Late Cretaceous syenite stock (Elliott, 1979). The historic Copper King mine exploited an unusual magmatic segregation deposit in the syenite stock. Zientek (1993b) describes the Goose Lake deposit as an example of a mineral deposit type characterized by small segregations of copper-rich magmatic sulfide minerals in alkaline intrusive rocks. Platinum + palladium (a few ppm to tens of ppm), silver (10 to 100 ppm range), and gold (<1 ppm) commonly accompany the copper ore (chalcopyrite and bornite) in these types of deposits.

All four samples from the Goose Lake area are copper-rich (≥8500 ppm Cu), and contain detectable (<1 ppm) gold and minor (4 to 150 ppm) silver. Chalcopyrite-rich samples 91JH62 and 91JH63 contain significant platinum and palladium; sample 91JH62 contains the platinum group elements rhodium and iridium as well. Sample 91JH67, a vuggy, sulfide-bearing rock composed of a mesh of quartz veins, is the most gold-rich rock sampled from the Goose Lake area (0.68 ppm). It also contains elevated concentrations of a number of elements relative to the other samples from the Goose Lake area, such as arsenic, lead, silver, bismuth, molybdenum, vanadium, and antimony.

Emigrant mining district (table 6)

The Emigrant mining district is centered on an eroded Tertiary volcanic complex associated with low-grade, disseminated (porphyry copper-gold-molybdenum type) mineralization. The Emigrant district was a major producer of placer gold in the early 1900's. Minor lode gold and silver were produced (Stotelmeyer and others, 1983). The porphyry potential has been explored repeatedly in the past 30 years - first for copper and molybdenum and more recently for gold. Three of the polymetallic, mineralized breccia pipes in the district, the Basic Metals breccia pipe (sample 91JH71),the Molybdenum breccia pipe (sample 91JH72), and the St. Julian breccia pipe (sample 91JH74) were sampled, along with several igneous rocks. These include altered Tertiary granodiorite porphyry as well as silicified flow-banded volcanic and hypabyssal intrusive rocks with disseminated sulfide minerals that occur in an area that was recently explored by Pegasus, Inc. for a shallow gold target.

Low-level gold (<1 ppm) is detected in all samples from the Emigrant area. Samples from a single location (91JH77a,b,c) are highly variable in metal content. Breccia samples are relatively enriched in base metals and molybdenum relative to the other samples. Copper values are 2,000 ppm or less in all samples.

Mill Creek area (tables 7 and 8)

Mill Creek is an east-west drainage along the northern margins of the Emigrant intrusive center. The geology of the area is described by Elliott and others (1983). Tertiary dacite porphyry from the Emigrant volcanoplutonic center covers much of the area, but Precambrian metamorphic rocks and Paleozoic sedimentary rocks are also exposed. Samples 91JH82 through 91JH87 were collected from Precambrian diorite and metadiorite near Burnt Creek, where anomalous platinum (along with copper, gold, silver, and nickel) was reported from U.S. Bureau of Mines sampling at the Copper Queen and Lost Cabin claims (Stotlemeyer and others, 1983). That study identified an inferred subeconomic resource of approximately 70,000 metric tons of potential ore averaging 0.48% copper, 5.1 grams per tonne (g/t) silver, and 0.08% nickel. This occurrence warranted further study because of its unusual chemical signature. Sample 91JH86 represents the least altered diorite. Sample 91JH88 is an amphibole-rich sample from the same diorite body exposed along West Fork Mill Creek.

Shear zones and contacts between Precambrian and Paleozoic rocks are an important control on the distribution of polymetallic vein (lead-zinc-silver ±gold) occurrences spatially related to the Emigrant intrusive center. The closest known exposures of copper-nickel resources are the disseminated to massive copper-nickel sulfide deposits near the base of the Stillwater Complex, well to the north of the Burnt Creek area and separated from it by major faults.

One or more platinum-group elements are detected in all samples, with the exception of 91JH86 and 91JH88. Gold concentrations range from below detection limits (<0.002 ppm) to 0.96 ppm. Samples with elevated platinum-group elements are also enriched in gold, silver, nickel, and copper relative to the other samples.

Sample 91JH96 was collected from a large Tertiary dacite porphyry body (Elliott and others, 1983, plate 1) that crops out along Mill Creek, north of the highly altered area immediately surrounding the Emigrant intrusive center. ICP-AES data are included in table 7. Major and trace element analyses by XRF and INAA data are reported in table 8. Although the rock appears relatively fresh, it contains moderately high water (1.5 weight percent) and carbon dioxide (1.4 weight percent) contents, indicating alteration. Figure 2A shows sample 91JH96 plotted on a TAS (total alkalis versus silica) diagram along with data from Chadwick (1970) for 8 other samples of igneous rocks from the Emigrant Peak area and northern Gallatin Range of the Absaroka-Gallatin volcanic province. The chondrite-normalized rare-earth element pattern for sample 91JH96 (fig. 2b) shows that the dacite porphyry is moderately enriched in light rare-earth elements (La is about 100 times chondrite) and lacks a europium anomaly.

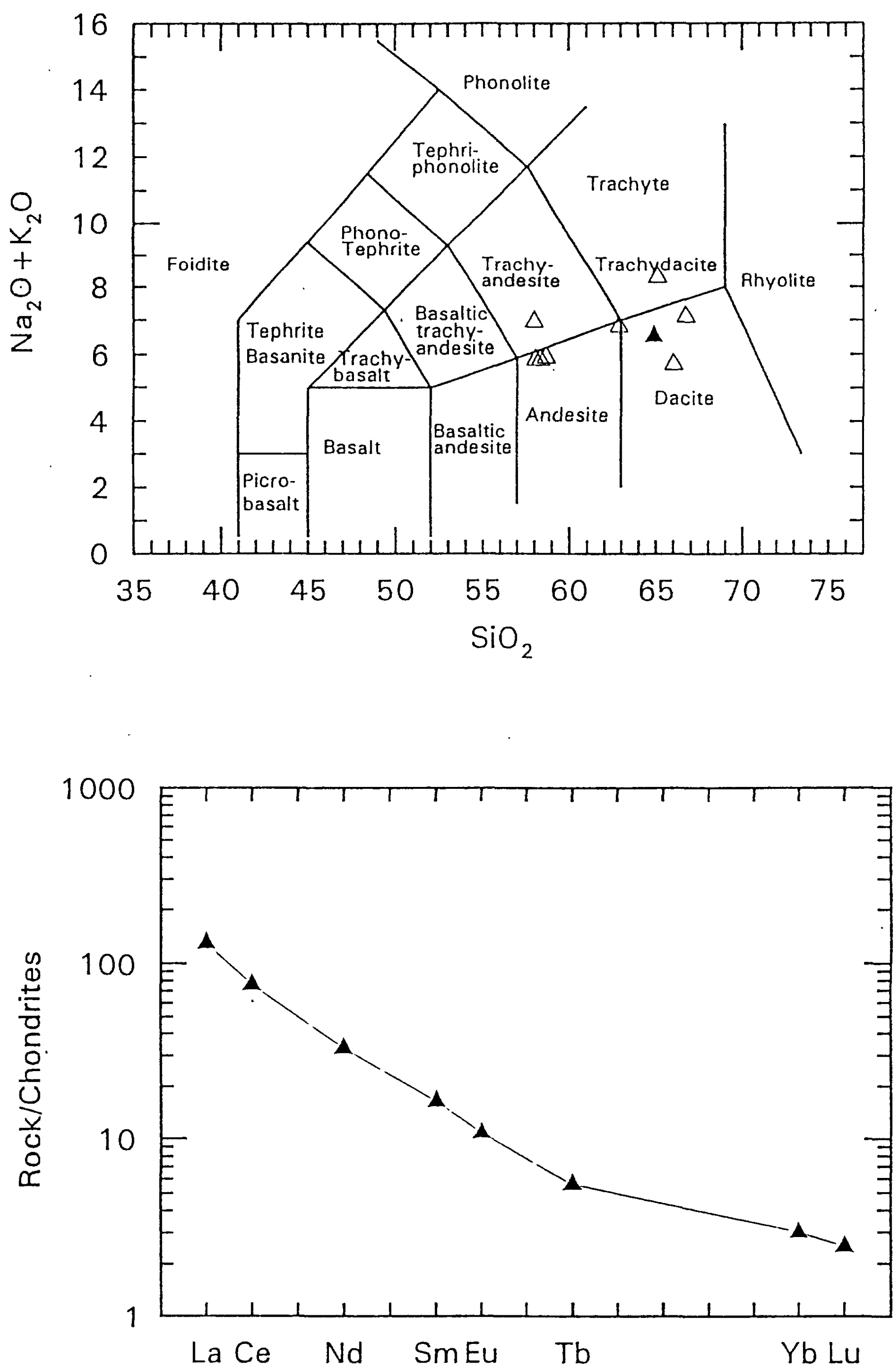

Figure 2. *A*, Total alkali-silica variation diagram for igneous rocks of the Absaroka-Gallatin volcanic province in the Emigrant Peak area and northern Gallatin Range. Solid triangle, sample 91JH96, this study. Open triangles, data from Chadwick (1970). Fields and rock names after Le Bas and others (1986). *B*, Chondrite-normalized rare earth element diagram for sample 91JH96 (using normalization factors from Nakamura, 1974).

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DATA TABLES

Table 1. Sample location information and descriptions

Field no.	Quadrangle	Location	Latitude	Longitude	Description
Sliderock Mountain area					
91JH07	Sliderock Mtn.	Fire Ridge	45 35 20 N	109 55 20 W	Magnetite skarn
91JH08	Sliderock Mtn.	Fire Ridge	45 35 20 N	109 55 20 W	Magnetite
91JH09	Sliderock Mtn.	Sliderock skarn	45 35 54 N	109 54 50 W	Massive magnetite
91JH10	Sliderock Mtn.	Sliderock skarn	45 35 54 N	109 54 50 W	Hornfels
91JH35	Sliderock Mtn.	ECM placer	45 35 54 N	109 56 18 W	Altered porphyry
91JH36	Sliderock Mtn.	ECM placer	45 35 54 N	109 56 18 W	Altered porphyry
91JH37	Sliderock Mtn.	Gold Hill mine	45 35 59 N	109 56 33 W	Altered porphyry
91JH38	Sliderock Mtn.	Gold Hill mine	45 35 59 N	109 56 33 W	Altered porphyry
91JH39	Sliderock Mtn.	N of Gold Hill mine	45 36 3 N	109 56 29 W	Gossan at prospect pit
91JH42	Sliderock Mtn.	S of Grouse Ridge	45 35 37 N	109 57 7 W	Skarnoid
Independence mining district					
91JH15	The Needles	War Eagle skarn	45 15 28 N	110 16 55 W	Garnet skarn
91JH16	The Needles	War Eagle skarn	45 15 30 N	110 16 46 W	Bedded skarn
91JH18	The Needles	War Eagle skarn	45 15 34 N	110 16 39 W	Oxidized ore
91JH19	The Needles	War Eagle skarn	45 15 34 N	110 16 39 W	Sulfide-rich skarn
91JH20	The Needles	War Eagle skarn	45 15 31 N	110 16 37 W	Sulfide-rich skarn
91JH30	Iron Mtn.	7777 Pb-Zn claim	45 12 37 N	110 15 36 W	Disseminated sulfides in metasedimentary rock
91JH31	Iron Mtn.	7777 Pb-Zn claim	45 12 37 N	110 15 36 W	Contact between Flathead Sandstone and Wolsey Shale
New World (Cooke City) mining district					
91JH55	Cooke City	N Scotch Bonnet Mtn	45 4 59 N	109 57 54 W	Altered Flathead Sandstone at adit
91JH56	Cooke City	N Scotch Bonnet Mtn	45 4 58 N	109 57 53 W	Altered Flathead Sandstone at adit
91JH57	Cooke City	N Scotch Bonnet Mtn	45 4 58 N	109 57 27 W	Altered andesite dike
91JH70	Cooke City	Black Warrior mine	45 2 59 N	109 57 47 W	Ore samples
Goose Lake area					
91JH61	Cooke City	Copper King mine	45 7 26 N	109 54 28 W	Syenite with sulfides
91JH62	Cooke City	Copper King mine	45 7 26 N	109 54 28 W	Sulfide-rich ore
91JH63	Cooke City	Copper King mine	45 7 26 N	109 54 28 W	Chalcopyrite vein
91JH67	Cooke City	Goose Lake	45 7 25 N	109 54 18 W	Silicifed rock

Table 1.--Continued

Field no.	Quadrangle	Location	Latitude	Longitude	Description
Emigrant mining district					
91JH71	Emigrant	Emigrant Gulch	45 16 16 N	110 40 48 W	Basic Metals breccia pipe
91JH72	Emigrant	Emigrant Gulch	45 15 36 N	110 40 13 W	Molybdenum breccia pipe
91JH73	Emigrant	Emigrant Gulch	45 15 27 N	110 39 54 W	Porphyry
91JH74	Emigrant	Emigrant Gulch	45 15 11 N	110 38 54 W	St. Julian mine
91JH75	Emigrant	Emigrant Gulch	45 15 3 N	110 39 26 W	Porphyry dike
91JH76	Emigrant	Emigrant Gulch	45 15 3 N	110 39 26 W	Silicified volcanic rock
91JH77	Emigrant	Emigrant Gulch	45 15 12 N	110 39 5 W	Volcanic rock
Mill Creek area					
91JH82	Knowles Peak	W Fork Mill Creek	45 17 16 N	110 35 11 W	Precambrian schist
91JH83	Knowles Peak	W Fork Mill Creek	45 17 16 N	110 35 9 W	Diorite with green stain
91JH84	Knowles Peak	Burnt Creek	45 17 16 N	110 35 10 W	Outcrop at adit
91JH85	Knowles Peak	Burnt Creek	45 17 16 N	110 35 10 W	Vuggy metadiorite with sulfides
91JH86	Knowles Peak	Burnt Creek	45 17 16 N	110 35 10 W	Diorite
91JH87	Knowles Peak	Burnt Creek	45 17 14 N	110 35 12 W	Trench sample
91JH88	Knowles Peak	W Fork Mill Creek	45 17 24 N	110 34 25 W	Precambrian amphibolite
91JH93	The Pyramid	Mill Creek road	45 16 20 N	110 29 48 W	Quartz vein in Precambrian rock
91JH96	Knowles Peak	Mill Creek road	45 16 56 N	110 30 30 W	Tertiary dacite porphyry

Table 2. Analytical data for rock samples from the Sliderock Mountain area
[n.d., not determined; N, not detected at the specified concentration]

Sample	91JH7a	91JH8	91JH9	91JH10b	91JH10c	91JH35a	91JH35b	91JH36	91JH37	91JH38	91JH39	91JH42
ICP-AES data, in weight percent												
Al	4.4	0.2	0.09	8.5	9.1	7.6	8.7	8.8	8.3	8.5	6.7	6.9
Ca	18	2.3	0.01	2.9	5.7	0.03	0.22	0.1	0.2	0.04	0.07	5.7
Fe	15	56	60	2.4	2.5	0.84	2.9	2.3	1.4	2.3	18	3.1
K	0.05	0.03	<0.02	5.1	0.79	7.2	3.1	4	2.6	3	2.2	3.8
Mg	1.2	0.64	1.5	1.6	2.8	0.26	0.2	0.37	0.34	0.36	0.2	2.8
Na	0.02	0.02	<0.01	2.9	4.3	0.45	1.9	1	2	1.4	0.03	1.3
P	0.05	<0.01	<0.01	0.09	0.1	0.04	0.1	0.09	0.09	0.1	0.08	0.09
Ti	0.1	<0.01	0.01	0.2	0.28	0.05	0.1	0.06	0.07	0.06	0.1	0.31
ICP-AES data, in parts per million												
Ag	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	6	<4
As	50	<20	<20	<20	<20	<20	<20	54	40	20	<20	<20
Au	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Ba	130	20	10	1800	320	5200	2300	3700	1300	2400	1500	1100
Be	<2	<2	<2	<2	<2	<2	2	<2	<2	<2	<2	<2
Bi	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	20	<20
Cd	<4	7	6	<4	<4	<4	<4	<4	<4	<4	20	<4
Ce	36	<8	<8	45	62	10	50	33	44	140	28	45
Co	24	53	110	20	9	4	6	4	3	3	4	10
Cr	20	<2	<2	33	20	10	20	10	20	20	22	48
Cu	51	84	250	140	830	8	140	4	63	10	400	7
Eu	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Ga	20	10	<8	20	20	20	21	24	20	22	10	10
Ho	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8
La	31	10	<4	29	51	10	31	23	27	85	20	26

Table 2.--Continued

Sample	91JH7a	91JH8	91JH9	91JH10b	91JH10c	91JH35a	91JH35b	91JH36	91JH37	91JH38	91JH39	91JH42
ICP-AES data, in parts per million												
Li	10	<4	<4	10	27	10	61	140	22	10	140	42
Mn	3300	1300	780	810	1100	41	280	32	44	33	640	610
Mo	10	<4	8	<4	20	7	<4	<4	<4	<4	<4	<4
Nb	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8
Nd	26	<8	<8	21	28	8	25	10	23	65	21	28
Ni	10	8	10	10	10	<4	10	<4	6	<4	10	20
Pb	10	<8	<8	9	<8	60	27	37	50	55	420	10
Sc	5	<4	<4	7	8	<4	<4	<4	<4	<4	6	10
Sn	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Sr	450	9	<4	370	700	320	580	290	470	720	590	1100
Ta	<80	<80	<80	<80	<80	<80	<80	<80	<80	<80	<80	<80
Th	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	9
U	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200
V	37	9	54	38	49	32	37	32	34	32	58	84
Y	8	<4	<4	10	10	<4	5	5	7	7	10	20
Yb	<2	2	3	<2	<2	<2	<2	<2	<2	<2	<2	<2
Zn	310	240	86	88	51	23	70	31	71	42	6600	95

Table 2.--Continued

Sample	91JH7a	91JH8	91JH9	91JH10b	91JH10c	91JH35a	91JH35b	91JH36	91JH37	91JH38	91JH39	91JH42
Solvent Extraction ICP-AES data, in parts per million												
Ag	N0.67	N1.0	N1.0	N0.067	N0.067	0.069	0.43	0.12	0.20	0.62	5.3	N0.067
As	25	N10	39	4.9	3.0	5.4	4.0	54	40	22	21	1.3
Au	N0.10	N1.5	N1.5	N0.10	N0.10	N0.10	N0.10	N0.10	N0.10	N0.10	N0.10	N0.10
Bi	N0.67	N10	N10	N0.67	N0.67	N0.67	N0.67	0.74	N0.67	0.79	14	N0.67
Cd	N0.050	N0.75	N0.75	0.18	N0.05	N0.02	0.092	N0.02	0.18	N0.020	15	0.035
Cu	35	110	310	110	1.3	5.4	120	4.3	54	11	390	3.6
Mo	8.9	1.2	6.8	0.30	9.3	4.6	0.35	0.99	0.73	1.1	3.9	1.3
Pb	10	N10	N10	7.0	5.4	21	7.5	28	49	53	430	4.4
Sb	N0.67	N10	N10	N0.67	N0.67	1.1	N0.67	2.5	2.2	1.4	N0.67	N0.67
Zn	340	300	120	93	38	8.6	47	14	46	18	>1200	59
GFAA data, in parts per million												
Au	0.002	<0.002	0.066	0.002	0.002	0.26	0.011	0.008	0.002	0.003	0.022	0.002
ICP-MS data, in parts per billion												
Pt	<3	<6	<6	<3	<3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Pd	<1	<2	<2	<1	<1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Rh	<1	<2	<2	<1	<1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ru	<1	<2	<2	<1	<1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ir	<1	<2	<2	<1	<1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

Table 3.--Analytical data for rock samples from the Independence mining district [n.d., not determined; N, not detected at the specified concentration]

Sample	91JH15	91JH16	91JH18	91JH19	91JH20	91JH30	91JH31
ICP-AES data, in weight percent							
Al	0.52	8.9	0.25	0.36	1	0.1	0.29
Ca	20	10	0.08	0.83	0.56	0.02	0.02
Fe	21	2.2	56	43	45	1.2	3.1
K	0.04	4.8	0.1	0.44	1.1	0.03	0.09
Mg	0.1	2	0.06	0.73	0.55	0.02	0.01
Na	0.01	0.65	0.02	0.01	0.04	<0.01	0.01
P	<0.01	0.05	0.02	0.02	0.01	<0.01	0.03
Ti	0.01	0.47	0.06	0.01	0.03	0.38	0.47
ICP-AES data, in parts per million							
Ag	<4	<4	<4	<4	<4	39	41
As	<20	<20	30	<20	<20	74	91
Au	<20	<20	<20	<20	<20	<20	<20
Ba	23	2700	29	10	67	130	180
Be	<2	3	<2	<2	<2	<2	<2
Bi	<20	<20	<20	<20	<20	<20	<20
Cd	5	<4	6	<4	4	<4	5
Ce	<8	76	<8	<8	<8	34	130
Co	6	20	34	50	50	6	10
Cr	3	59	<2	<2	4	7	20
Cu	<2	210	180	1600	2100	41	480
Eu	<4	<4	<4	<4	<4	<4	<4
Ga	28	20	28	<8	20	<8	<8
Ho	<8	<8	<8	<8	<8	<8	<8
La	<4	41	<4	<4	<4	24	100

Table 3.--Continued

Sample	91JH15	91JH16	91JH18	91JH19	91JH20	91JH30	91JH31
ICP-AES data, in parts per million							
Li	<4	10	4	<4	7	6	7
Mn	4800	830	430	510	1000	10	9
Mo	<4	<4	22	4	5	7	6
Nb	<8	24	<8	<8	<8	9	10
Nd	<8	46	<8	<8	<8	10	42
Ni	<4	26	28	20	20	10	22
Pb	40	10	<8	<8	<8	33000	8600
Sc	<4	10	6	10	4	4	<4
Sn	<10	<10	<10	<10	<10	<10	<10
Sr	36	750	10	10	20	10	350
Ta	<80	<80	<80	<80	<80	<80	<80
Th	<8	20	<8	<8	<8	20	26
U	<200	<200	<200	<200	<200	<200	<200
V	10	46	610	110	150	7	10
Y	<4	38	<4	<4	<4	10	20
Yb	<2	4	<2	<2	<2	<2	<2
Zn	10	130	170	100	200	260	740

Table 3.--Continued

Sample	91JH15	91JH16	91JH18	91JH19	91JH20	91JH30	91JH31
Solvent Extraction ICP-AES data, in parts per million							
Ag	N0.067	0.29	0.21	0.63	0.71	26	30
As	7.2	1.2	33	10	14	25	27
Au	N0.10	N0.10	N0.10	N0.80	N0.80	N0.80	N0.10
Bi	N0.67	N0.67	N0.67	N5.3	N5.3	N5.3	1.6
Cd	0.080	0.13	0.083	N0.16	0.32	0.79	3.8
Cu	1.0	170	160	1500	1900	5.3	20
Mo	2.1	0.42	11	1.9	1.1	3.2	3.8
Pb	6.1	8.0	5.0	N5.3	N5.3	28000	8400
Sb	1.2	N0.67	44	10	35	32	45
Zn	13	33	84	64	N0.16	81	440
GFAA data, in parts per million							
Au	0.002	0.011	0.042	0.53	0.22	0.06	0.063
ICP-MS data, in parts per billion							
Pt	n.d.	n.d.	n.d.	<3	n.d.	n.d.	n.d.
Pd	n.d.	n.d.	n.d.	9.2	n.d.	n.d.	n.d.
Rh	n.d.	n.d.	n.d.	<1	n.d.	n.d.	n.d.
Ru	n.d.	n.d.	n.d.	<1	n.d.	n.d.	n.d.
Ir	n.d.	n.d.	n.d.	<1	n.d.	n.d.	n.d.

Table 4.--Analytical data for rock samples from the New World (Cooke City) mining district
[n.d., not determined; N, not detected at the specified concentration]

Sample	91JH55a	91JH55b	91JH56a	91JH56b	91JH57	91JH70f
ICP-AES data, in weight percent						
Al	1.6	6.9	2.3	1.3	8.5	0.39
Ca	0.04	0.05	0.1	0.1	2.4	0.53
Fe	1.6	1.5	1.5	1.5	3	37
K	0.76	6.8	1	0.57	2.9	0.2
Mg	0.07	0.1	0.1	0.1	0.7	0.06
Na	0.02	0.2	0.02	0.01	2.2	<0.01
P	0.03	0.04	0.06	0.04	0.07	0.03
Ti	0.02	0.05	0.08	0.04	0.2	0.02
ICP-AES data, in parts per million						
Ag	<4	7	<4	22	10	2400
As	<20	<20	<20	53	30	40
Au	<20	<20	<20	<20	<20	78
Ba	150	3600	1600	2200	830	21
Be	<2	<2	<2	<2	<2	<2
Bi	<20	<20	<20	<20	<20	<20
Cd	<4	<4	<4	<4	<4	<4
Ce	31	20	30	<8	40	10
Co	3	6	8	10	9	21
Cr	29	10	28	28	43	20
Cu	20	72	10	32	26	480
Eu	<4	<4	<4	<4	<4	<4
Ga	<8	10	9	<8	20	<8
Ho	<8	<8	<8	<8	<8	<8
La	20	9	20	6	30	10

	91JH55a	91JH55b	91JH56a	91JH56b	91JH57	91JH70f
ICP-AES data, in parts per million						
Li	28	8	10	10	7	<4
Mn	290	340	4100	2100	580	94
Mo	<4	<4	<4	<4	<4	6
Nb	<8	<8	<8	<8	<8	<8
Nd	20	9	10	<8	20	8
Ni	9	10	20	23	20	29
Pb	500	990	360	1800	58	4200
Sc	<4	<4	<4	<4	<4	<4
Sn	<10	<10	<10	<10	<10	<10
Sr	37	130	59	56	530	6
Ta	<80	<80	<80	<80	<80	<80
Th	<8	<8	10	<8	<8	<8
U	<200	<200	<200	<200	<200	<200
V	20	10	26	24	45	10
Y	<4	<4	6	<4	<4	<4
Yb	<2	<2	<2	<2	<2	<2
Zn	190	160	46	35	240	68

Table 4.--Continued

Sample	91JH55a	91JH55b	91JH56a	91JH56b	91JH57	91JH70f
Solvent Extraction ICP-AES data, in parts per million						
Ag	1.6	5.8	1.9	20	2	2300
As	13	7.4	12	56	15	N5.3
Au	N0.10	N0.10	N0.10	N0.10	N0.10	81
Bi	N0.67	0.98	N0.67	2.5	N0.67	N5.3
Cd	0.14	0.19	0.13	0.24	0.95	0.36
Cu	15	37	5.5	31	12	100
Mo	0.52	0.54	1.9	0.87	0.96	1.2
Pb	470	960	320	2000	40	4600
Sb	0.85	1.5	1.6	3.6	0.68	6.1
Zn	140	130	27	28	190	39
GFAA data, in parts per million						
Au	0.006	0.007	0.002	0.009	0.02	68
ICP-MS data, in parts per billion						
Pt	n.d.	n.d.	n.d.	<3	n.d.	n.d.
Pd	n.d.	n.d.	n.d.	<1	n.d.	n.d.
Rh	n.d.	n.d.	n.d.	<1	n.d.	n.d.
Ru	n.d.	n.d.	n.d.	<1	n.d.	n.d.
Ir	n.d.	n.d.	n.d.	<1	n.d.	n.d.

Table 5.--Analytical data for rock samples from the Goose Lake area

[n.d., not determined; N, not detected at the specified concentration]

Sample	91JH61	91JH62	91JH63	91JH67
ICP-AES data, in weight percent				
Al	9.6	4.6	2.4	1.7
Ca	0.32	0.05	0.03	0.03
Fe	1.7	16	14	13
K	8.8	4.6	2.2	1.7
Mg	0.1	0.07	<0.01	0.07
Na	2.3	0.86	0.7	0.04
P	0.07	0.37	0.34	0.09
Ti	0.1	0.1	0.03	0.02
ICP-AES data, in parts per million				
Ag	4	68	68	150
As	<20	<20	<20	3300
Au	<20	<20	<20	<20
Ba	1200	51	88	36
Be	<2	<2	<2	<2
Bi	<20	<20	<20	110
Cd	<4	20	20	8
Ce	42	<8	<8	<8
Co	5	77	83	10
Cr	4	<2	<2	9
Cu	8500	190000	180000	31000
Eu	<4	<4	<4	<4
Ga	27	10	<8	<8
Ho	<8	<8	<8	<8
La	22	4	<4	<4

Sample	91JH61	91JH62	91JH63	91JH67
ICP-AES data, in parts per million				
Li	29	<4	<4	20
Mn	180	200	20	41
Mo	<4	<4	<4	86
Nb	<8	<8	<8	25
Nd	20	8	<8	<8
Ni	<4	<4	20	42
Pb	27	34	26	2300
Sc	<4	<4	<4	<4
Sn	<10	<10	10	23
Sr	1300	1500	280	29
Ta	<80	<80	<80	<80
Th	<8	<8	<8	<8
U	<200	<200	<200	<200
V	83	57	8	2700
Y	10	<4	<4	<4
Yb	<2	<2	<2	<2
Zn	76	770	1200	740

Table 5.--Continued

Sample	91JH61	91JH62	91JH63	91JH67
Solvent Extraction ICP-AES data, in parts per million				
Ag	2.8	59	59	110
As	5.1	N10	N10	2200
Au	N0.10	N1.5	N1.5	N0.80
Bi	N0.67	N10	N10	N5.3
Cd	0.84	16	8.5	0.45
Cu	>2000	>30000	>30000	>10000
Mo	0.16	N0.90	N0.90	34
Pb	11	140	110	2300
Sb	9.1	190	160	730
Zn	54	590	880	N0.16
GFAA data, in parts per million				
Au	0.007	0.099	0.077	0.68
ICP-MS data, in parts per billion				
Pt	72	5800	590	n.d.
Pd	63	4300	1800	n.d.
Rh	<1	7	1	n.d.
Ru	<1	<5	<1	n.d.
Ir	<1	36	<1	n.d.

Table 6.--Analytical data for rock samples from the Emigrant mining district
[N, not detected at the specified concentration]

Sample	91JH71	91JH72	91JH73	91JH74c	91JH75	91JH76	91JH77a	91JH77b	91JH77C
ICP-AES data, in weight percent									
Al	6.1	6.2	7.5	8	7.9	6.9	7.3	8.1	8.3
Ca	0.01	0.006	0.83	0.17	1	0.13	0.04	0.14	0.17
Fe	1.3	2.4	2.2	2.8	1.9	1.1	0.94	2.2	1.3
K	4.4	3.1	2.8	3.5	3.1	3.8	7.4	3.8	4.8
Mg	0.08	0.24	0.83	0.52	0.22	0.04	0.1	0.15	0.14
Na	0.1	0.06	2.6	2.4	2.2	2.2	0.89	2.5	2.6
P	0.009	0.01	0.06	0.07	0.05	0.009	0.02	0.06	0.05
Ti	0.07	0.06	0.11	0.2	0.1	0.02	0.06	0.06	0.06
ICP-AES data, in parts per million									
Ag	4	<2	<2	<2	<2	<2	<2	<2	<2
As	270	26	20	<10	<10	<10	42	53	10
Au	<8	<8	<8	<8	<8	<8	<8	<8	<8
Ba	940	220	950	1800	2000	720	1400	330	1100
Be	2	2	2	2	2	2	1	1	2
Bi	<10	<10	20	<10	<10	<10	<10	<10	<10
Cd	3	<2	<2	<2	<2	<2	<2	<2	<2
Ce	55	160	94	72	69	62	140	34	110
Co	2	5	10	7	10	1	1	<1	3
Cr	<1	5	49	64	33	<1	1	6	6
Cu	270	67	2000	190	4	19	45	910	330
Eu	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ga	14	15	19	23	21	14	17	16	18
Ho	<4	<4	<4	<4	<4	<4	<4	<4	<4
La	34	110	67	50	51	40	89	18	68

Table 6.--Continued

Sample	91JH71	91JH72	91JH73	91JH74c	91JH75	91JH76	91JH77a	91JH77b	91JH77C
ICP-AES data, in parts per million									
Li	17	19	10	13	21	6	5	7	7
Mn	260	27	180	140	940	12	28	46	68
Mo	<2	4600	<2	<2	<2	<2	<2	<2	<2
Nb	9	7	6	<4	<4	<4	8	5	<4
Nd	22	53	30	35	23	22	54	16	44
Ni	<2	4	23	17	13	<2	<2	<2	2
Pb	1200	21	16	30	22	42	64	22	13
Sc	4	4	5	5	3	3	5	5	5
Sn	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sr	30	25	330	200	320	80	98	170	160
Ta	<40	<40	<40	<40	<40	<40	<40	<40	<40
Th	15	17	15	14	12	15	21	12	13
U	<100	<100	<100	<100	<100	<100	<100	<100	<100
V	2	14	39	50	31	<2	2	11	10
Y	7	9	10	15	6	5	11	5	11
Yb	<1	<1	<1	2	<1	<1	1	<1	<1
Zn	580	9	51	57	140	5	17	41	21

Table 6.--Continued

Sample	91JH71	91JH72	91JH73	91JH74c	91JH75	91JH76	91JH77a	91JH77b	91JH77C
Solvent Extraction ICP-AES data, in parts per million									
Ag	3.3	1.3	1.3	0.28	0.15	0.19	0.22	0.89	0.24
As	220	2.5	N5.3	1.8	N0.67	2.0	9.6	21	1.6
Au	N0.10	N0.10	N0.80	N0.10	N0.10	N0.10	N0.10	0.21	0.10
Bi	N0.67	1.9	20	N0.67	N0.67	N0.67	2	11	N0.67
Cd	2.5	N0.02	0.88	0.083	0.085	N0.02	N0.02	0.027	0.27
Cu	220	51	2100	160	1.7	15	37	870	300
Mo	1.7	370	0.63	1.5	0.22	1.8	0.69	0.92	1.8
Pb	1200	13	12	14	11	20	48	17	5.6
Sb	3	N0.67	N5.3	N0.67	N0.67	N0.67	N0.67	1.6	N0.67
Zn	420	N0.020	49	35	92	N0.020	N0.020	27	17
GFAA data, in parts per million									
Au	0.11	0.048	0.088	0.007	0.006	0.005	0.004	0.84	0.04

Table 7.--Analytical data for rock samples from the Mill Creek area
[n.d., not determined; N, not detected at the specified concentration]

Sample	91JH82	91JH83	91JH84a	91JH84b	91JH85	91JH86	91JH87	91JH88	91JH93	91JH96
ICP-AES data, in weight percent										
Al	3.4	8.1	9.6	12	7.5	9.1	7.2	8.2	8.2	7.1
Ca	2.2	7.3	5.6	9.1	7.4	6.7	2.2	7.3	0.76	2.7
Fe	24	9	9.5	8	9.2	7.6	12	7.6	0.45	2.6
K	0.29	0.46	0.03	0.07	0.1	0.69	0.54	0.33	0.48	2.7
Mg	2.7	4.3	3.2	2.7	4.3	5.2	2.7	5.3	0.09	1.3
Na	0.22	1.5	0.2	0.4	0.97	1.5	1.2	1.3	4.9	2.7
P	0.1	0.04	<0.01	<0.01	0.02	0.01	0.27	0.01	0.05	0.07
Ti	0.09	0.68	1.1	0.84	0.5	0.2	0.9	0.27	0.03	0.26
ICP-AES data, in parts per million										
Ag	<4	<4	<4	<4	<4	44	<4	<2	<2	<2
As	<20	<20	<20	<20	<20	<20	13000	<20	24	<10
Au	<20	<20	<20	<20	<20	<20	<20	<20	<8	<8
Ba	81	130	8	20	25	150	120	120	250	190
Be	<2	<2	<2	<2	<2	<2	<2	6	6	2
Bi	<20	<20	<20	<20	<20	<20	<20	<10	<10	<10
Cd	<4	<4	<4	<4	<4	9	<4	<2	<2	<2
Ce	10	<8	9	<8	<8	<8	23	<8	13	70
Co	37	47	21	20	63	51	43	54	2	16
Cr	81	320	380	270	320	210	270	130	4	54
Cu	540	910	500	270	6000	86	65000	67	8	19
Eu	<4	<4	<4	<4	<4	<4	<4	<2	<2	<2
Ga	<8	20	28	40	10	10	<8	10	23	19
Ho	<8	<8	<8	<8	<8	<8	<8	<8	<4	<4
La	9	4	6	8	6	<4	20	<4	8	48

Table 7.--Analytical data for rock samples from the Mill Creek area

Sample	91JH82	91JH83	91JH84a	91JH84b	91JH85	91JH86	91JH87	91JH88	91JH93	91JH96
ICP-AES data, in parts per million										
Li	6	20	36	31	10	29	40	20	9	48
Mn	2000	2200	1200	1200	1400	1200	530	1300	86	360
Mo	<4	<4	<4	<4	<4	<4	<4	<4	<2	<2
Nb	<8	<8	10	9	<8	<8	<8	<8	4	7
Nd	20	10	<8	10	10	<8	20	<8	7	21
Ni	650	280	280	210	570	170	8000	140	5	39
Pb	<8	84	<8	<8	<8	<8	23	<8	16	32
Sc	10	41	80	76	42	33	23	40	<2	4
Sn	<10	<10	<10	<10	<10	<10	<10	<10	<5	<5
Sr	10	120	140	240	110	110	96	120	200	450
Ta	<80	<80	<80	<80	<80	<80	<80	<80	<40	<40
Th	9	<8	<8	<8	<8	<8	<8	<8	7	8
U	<200	<200	<200	<200	<200	<200	<200	<200	<100	<100
V	27	260	460	560	280	140	200	200	5	57
Y	10	20	6	7	10	6	20	9	6	6
Yb	2	2	<2	2	<2	<2	<2	<2	<1	<1
Zn	94	370	59	51	90	77	270	88	14	67

Table 7.--Continued

Sample	91JH82	91JH83	91JH84a	91JH84b	91JH85	91JH86	91JH87	91JH88	91JH93	91JH96
Solvent Extraction ICP-AES data, in parts per million										
Ag	0.50	0.31	0.21	0.20	0.72	N0.067	28	N0.067	N0.067	N0.067
As	N0.67	6.1	8.3	3.0	N0.67	N0.67	>2400	45	13	1.2
Au	N0.10	N0.10	N0.10	N0.10	N0.10	N0.10	N0.10	N0.10	N0.10	N0.10
Bi	N0.67	2.2	N0.67	N0.67	N0.67	N0.67	42	N0.67	N0.67	N0.67
Cd	N0.050	1.2	N0.050	N0.050	N0.050	0.051	10	N0.050	N0.02	N0.050
Cu	560	910	510	250	>2000	73	>2000	81	6.7	21
Mo	0.14	0.12	0.90	0.69	N0.060	0.078	N0.060	0.085	0.11	0.59
Pb	1.3	73	3.6	1.8	9.4	4.7	26	2.5	7.8	12
Sb	N0.67	0.84	0.81	N0.67	6.5	N0.67	110	N0.67	N0.67	N0.67
Zn	32	120	46	34	28	35	9.0	34	10	59
GFAA, in parts per million										
Au	0.023	<0.002	0.011	0.017	0.058	<0.002	0.96	0.002	0.002	n.d.
ICP-MS, in parts per billion										
Pt	5	<3	27	24	110	<3	200	<3	n.d.	n.d.
Pd	8	1	24	9.3	83	<1	400	<1	n.d.	n.d.
Rh	<1	<1	1	<1	8.2	<1	4.7	<1	n.d.	n.d.
Ru	<1	<1	<1	<1	9.5	<1	<1	<1	n.d.	n.d.
Ir	<1	<1	<1	<1	4.6	<1	<1	<1	n.d.	n.d.

Table 8.--Analytical data for dacite porphyry sample 91JH96 (Mill Creek area)
[$FeTO_3$, total iron reported as Fe_2O_3; LOI, loss on ignition at 925 °C]

Major element XRF data

(Weight percent)

SiO_2	64.9
Al_2O_3	14.7
$FeTO_3$	3.53
MgO	2.12
CaO	3.28
Na_2O	3.37
K_2O	3.15
TiO_2	0.51
P_2O_5	0.16
MnO	0.05
LOI	3.57
FeO	1.6
H_2O+	1.5
H_2O-	0.76
CO_2	1.4
F	0.051
Cl	0.014

XRF trace element data

(parts per million)

Nb	<10
Rb	75
Sr	468
Zr	147
Y	9

INAA trace element data

(Weight percent)

Na	2.67
K	2.71
Ca	2.39
Ti	1.2
Fe	2.54

(Parts per million)

Sc	5.74
Cr	64.0
Co	11.45
Ni	38
Zn	53.0
As	1.01
Se	<0.4
Rb	69.8
Sr	481
Zr	168
Mo	<1
Sb	0.327
Cs	3.56
Ba	1790
La	42.6
Ce	65.9
Nd	20.8
Sm	3.33
Eu	0.827
Tb	0.263
Yb	0.66
Lu	0.085
Hf	3.65
Ta	0.540
Au	<3
Th	9.27
U	1.69