Interpretation of Reconnaissance Geochemical Data from the Port Moller, Stepovak Bay, and Simeonof Island Quadrangles, Alaska Peninsula, Alaska

By J.G. Frisken

Porphyry copper- and molybdenum-type sulfide systems
and precious-metal systems are delineated in the study area
by interpretation of geochemical data

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Interpretation of Reconnaissance Geochemical Data from the Port Moller, Stepovak Bay, and Simeonof Island Quadrangles, Alaska Peninsula, Alaska

By J.G. Frisken

Abstract

During the 1983 through 1985 field seasons, the U.S. Geological Survey conducted a reconnaissance stream-sediment geochemical survey of the Port Moller, Stepovak Bay, and Simeonof Island 1°×2° quadrangles on the Alaska Peninsula. This study is based primarily on emission-spectrographic data plus atomic-absorption gold data obtained from the analysis of minus-80-mesh stream-sediment samples and from the analysis of nonmagnetic heavy-mineral-concentrate and bulk-concentrate samples derived from stream sediment.

Interpretation of the analytical data delineates zones enriched in gold and zones enriched in copper plus molybdenum. The zones enriched in copper plus molybdenum are located within zones of hydrothermally altered volcanic and clastic rocks that are spatially associated with intrusive bodies of intermediate composition. The zones of alteration and copper-plus-molybdenum enrichment are thought to indicate the presence of porphyry copper- and molybdenum-type sulfide systems that may include associated base- and precious-metal veins. Most zones of gold-rich rocks overlap zones of rocks enriched in copper plus molybdenum; this suggests a possible genetic relationship. However, some quartz-sulfide-vein samples containing relatively high concentrations of gold were collected in the vicinity of the Devils batholith from intrusive or country rocks that were not obviously enriched in copper plus molybdenum.

Base-metal veins in the study area generally contain either precious metals or are spatially associated with precious-metal veins. Common minerals in the base-metal veins include quartz, calcite, pyrite, chalcopyrite, galena, and sphalerite. Antimony, arsenic, and bismuth minerals are also often present in these veins.

Geochemical maps (plates 1 and 2) show anomalous areas that include, but are not limited to, areas with known mineral prospects. These maps indicate favorable new targets for mineral exploration.

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INTRODUCTION

A reconnaissance geochemical survey was conducted within the Port Moller, Stepovak Bay, and Simeonof Island 1°×2° quadrangles from 1983 through 1985. For this report, these quadrangles are referred to as the Port Moller study area. This survey represents a part of the Level III 1:250,000-scale Alaska Mineral Resource Assessment Program (AMRAP). Samples of stream sediments and heavy-mineral concentrates were collected during this survey and analyzed by semiquantitative emission spectrography. Data from rock samples collected during the reconnaissance geochemical survey (Arbogast and others, 1987) and during geologic mapping studies (Angeloni and others, 1985; Wilson and others, 1987) are also discussed. Most rock samples and selected panned-concentrate and stream-sediment samples collected were analyzed for gold by atomic absorption spectrophotometry. Stream-sediment and panned-concentrate geochemical data and gold data obtained from all sample media are interpreted in this report. Extensive reference is made to anomaly distribution maps for stream-sediment data (Frisken and Arbogast, 1991a), nonmagnetic heavy-mineral-concentrate data (Frisken and Arbogast, 1991b), and for gold data from all sample media (Frisken and Kelley, 1991). Unreferenced discussions of the geology of the study area, presented throughout this paper, are from F.H. Wilson (written commun., 1989), the AMRAP geological map (Wilson and others, in press), or from field observations made during the reconnaissance geochemical survey

Physiographic and Geologic Setting

The land area of the Port Moller study area (fig. 1) comprises about 8,800 km^2 on the Alaska Peninsula and offshore islands. Few roads exist in the study area. Access is by ferry

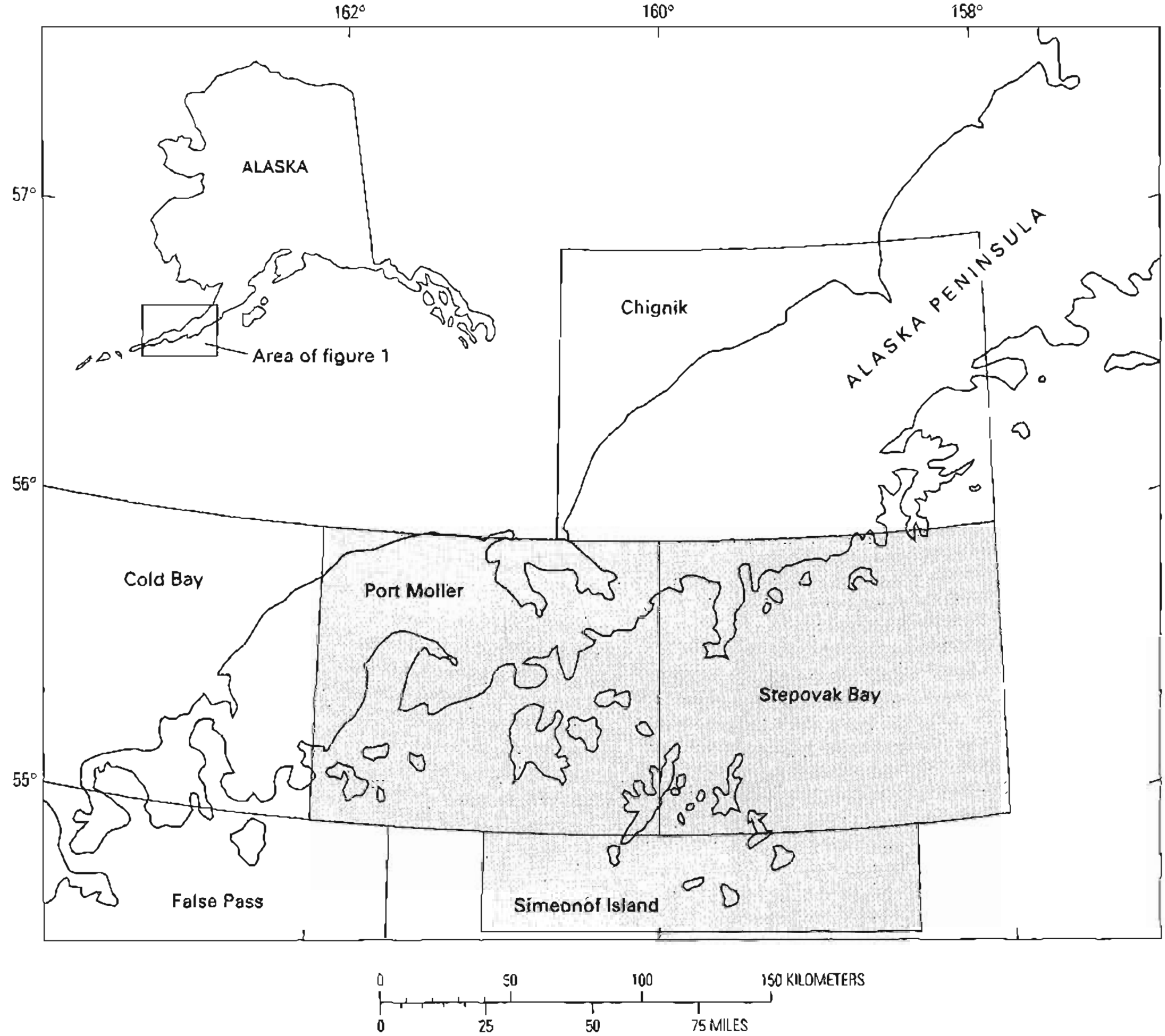


Figure 1. Index map of the Alaska Peninsula showing location of Port Moller study area.

or airplane to Sand Point located on Popof Island, and to Ivanof, Perryville, Port Moller, and Nelson Lagoon by chartered boat or plane. The climate is moderated by the effect of the Japanese Current and moist conditions have led to luxuriant vegetation below about 450 m throughout most of the study area. The vegetation consists primarily of low-growing plants, but salmonberry and alder thickets occur along some drainages.

The study area is part of the Nushagak–Bristol Bay Lowland and Aleutian Range physiographic provinces (Wahrhaftig, 1965). The part of the Aleutian Range province within the study area is characterized by glaciated peaks having average elevations near 1,000 m. Several Holocene volcanic peaks dominate the landscape. The northwestern part of the study area is in the Nushagak–Bristol Bay Lowland province and is characterized by less than 50 m of relief.

The most comprehensive report covering the geology of the study area prior to the AMRAP study was a reconnaissance stratigraphic study by Burk (1965). The Pavlof volcanic centers were mapped by Kennedy and Waldron (1955) and part of the outer Shumagin Islands was mapped by Moore (1974). The Port Moller AMRAP geologic map (Wilson and others, in press) combines elements of these studies with extensive new field mapping.

Mesozoic rocks in the study area are entirely sedimentary and range in age from Late Jurassic to Late Cretaceous. The oldest rocks in the area are sandstone and siltstone of the Upper Jurassic Naknek Formation. These rocks are conformably overlain by siltstone and shale of the Lower Cretaceous Staniukovich Formation and the stratigraphically higher calcarenite of the Herendeen Formation. Overlying these units are Upper Cretaceous clastic rocks of the Chignik, Hoodoo, and Shumagin Formations (Burk, 1965; Detterman and others, in press).

Episodes of volcanism occurred during the Tertiary and earlier Quaternary and continue into the present day. The large granodiorite batholith in the Shumagin Islands and the Paleocene nonvolcanic sandstone in the Tolstoi Formation are the oldest Tertiary rocks known in the area. The upper part (Eocene) of the Tolstoi Formation is rich in volcanic debris and is the earliest evidence for volcanic activity related to the Meshik magmatic arc of Wilson (1985). Eocene and Oligocene volcanic sandstone and siltstone of the Stepovak Formation and volcanic rocks of the Meshik Volcanics and correlative units, including the Popof volcanic rocks, constitute the main part of the Meshik arc. Meshik arc volcanism ceased in middle Miocene time with the deposition of the uppermost part of the Unga Formation, which includes lahars associated with volcanic centers on Unga Island. The tuffaceous clastic rocks of the upper Oligocene(?) to middle Miocene(?) Belkofski Formation may be, at least in part, correlative with the Unga Formation. The nonvolcanic Miocene Bear Lake Formation was deposited during a time of volcanic quiescence. Late Miocene volcanic and intrusive rocks indicate the initiation of Aleutian arc magmatic activity. The Pliocene Milky River Formation is the youngest recognized Tertiary geologic unit in the area and is composed mainly of volcanic flows and sandstone. During Quaternary time, additional volcanic units, hypabyssal plugs, and domes were emplaced and much of the lowland part of the study area was covered by alluvial, colluvial, lacustrine, glacial, and marine beach deposits.

Mineral Occurrences on the Alaska Peninsula

Known mineral occurrences on the Alaska Peninsula are dominated by porphyry-type copper-molybdenum sulfide systems. In the Chignik–Sutwik Island study area, immediately north of the Port Moller study area, Wilson and Cox (1983) described porphyry mineralization associated with early Tertiary to Quaternary intrusive rocks of intermediate composition that intruded marine and nonmarine clastic rocks. Wilson and Cox (1983) also stated that copper- and molybdenum-rich porphyry systems were characterized by drainage basins in which stream sediments were anomalous in copper, molybdenum, and tungsten; these basins were surrounded by drainage basins in which stream sediments were anomalous in lead, zinc, bismuth, arsenic, and precious metals. Rocks exposed in basins with copper-molybdenum-tungsten anomalies typically showed argillic, sericitic, or phyllic alteration and contained disseminated molybdenite, chalcopyrite, and scheelite. Surrounding the zones of intense alteration were zones of propylitically altered rocks containing both disseminated and vein pyrite and lesser amounts of galena, sphalerite, arsenopyrite, precious metals, barite, and tourmaline. Some placer gold was found in streams surrounding the centers of mineralization. Weathering and oxidation of exposed pyrite commonly produced yellow-brown and reddish color anomalies. Observations made during the present study indicate that similar geologic and geochemical features are associated with centers of mineralization in the Port Moller study area. However, most samples with detectable tungsten concentrations and most nonmagnetic heavy-mineral-concentrate samples that contained scheelite were collected from the central Shumagin Islands, an area primarily underlain by the Shumagin Islands batholith.

Mineral Deposits of the Port Moller Study Area

Known mineral occurrences in the Port Moller study area include porphyry copper and molybdenum deposits and base- and precious-metal vein deposits. Hydrothermally altered rocks associated with both the Meshik and Aleutian magmatic arcs are common within the study area and indicate areas that may host mineral deposits. In the late 1800's, gold prospecting led to the establishment of the Apollo gold mine, located near the head of Delarof Harbor on Unga Island. Between 1892 and 1912, the Apollo and nearby Sitka mines produced more than 107,900 oz of gold from ore that averaged about 0.22 oz/ton. The bulk of the gold produced was from quartz-sulfide veins, which were exceedingly rich in places (Atwood, 1911). Additional reserves discovered in recent years may amount to 1,453,600 tons of ore grading at 0.317 oz/ton gold and 1.37 oz/ton silver (Green and others, 1989). Recent exploration has also found ore reserves on Unga Island at the Shumagin deposit, located near the head of Baral of Bay. This deposit has reserves of 278,201 tons of ore grading at 0.524 oz/ton gold and 2.47 oz/ton silver (Green and other, 1989). In addition, the Aquila prospect, located southeast of the Shumagin gold deposit near Acheredin Bay, has an estimated 30,000 tons of ore grading at 0.22 oz/ton gold and 0.8 oz/ton silver (Wilson and others, 1988). All of the precious-metal reserves are located in open-growth quartz veins that are hosted by andesite flows and tuffs. The host rocks have undergone extensive propylitic alteration and local argillic and sericitic alteration along fracture zones. Between 3,000 and 4,000 oz of placer gold were also recovered, primarily in 1904 and 1905, from beach gravels near Sand Point, the site of the present-day airport on Popof Island (B.S. Webber, J.M. Moss, F.A. Rutledge, and R.S. Sanford, U.S. Bureau of Mines, written commun., 1946). Upland source rocks are presently being reevaluated for gold-ore reserves.

Since the 1950's, copper exploration has located small porphyry copper systems at Pyramid Mountain (Armstrong and others, 1976) and at the Ivanof porphyry copper prospect northwest of Humpback Bay (Mackevett and Holloway, 1977). These mineral systems feature quartz diorite intruded into clastic rocks and show zoned alteration patterns that include potassic cores, pervasive sericitic alteration with veinlet and replacement mineralization, and propylitic margins. The Pyramid porphyry copper prospect was drilled in 1975 and has reserves of 126 million tons of ore averaging 0.413 percent copper and 0.025 percent molybdenum (Christie, 1975; Christie and Wolfhard, 1977; Armstrong and others, 1976). The Ivanof porphyry copper prospect has reported grades as high as 0.72 percent copper with potential for large tonnages (Green and others, 1989). Gold is associated with known porphyry copper-molybdenum occurrences in the study area (Frisken and Arbogast, 1991b; Wilson and others, 1988) and may be a significant by-product if any of these occurrences prove to be of economic significance.

GEOCHEMICAL METHODS

Heavy-mineral-concentrate and stream-sediment samples were collected from active stream channels, most draining areas of 1–8 km^2. Sample density is highest in areas of visible phyllic or argillic alteration that are often characterized by extensive red color anomalies. Overall sample density is lowest in the swampy lowlands near the Bering Sea coast where pre-Holocene outcrops are rare. During the reconnaissance geochemical sampling program, 777 stream-sediment samples and 939 panned-concentrate samples were collected. Both sample media were collected by wet sieving through a 10-mesh stainless steel screen. At each site, one 36-cm (14-in) gold pan of sediment was collected and about 0.5 kg of minus-2-mm material was retained as the stream-sediment sample. The remaining material was panned at the site to produce a heavy-mineral concentrate. At 161 sites, a second concentrate sample was collected solely for low-level gold analysis.

The minus-2-mm stream-sediment samples were dried in an oven and then shipped to the laboratory where they were sieved through an 80-mesh screen. This fraction was ground between ceramic plates to minus-150 mesh and retained for chemical analysis. The panned concentrates were dried in an oven and then shipped to the laboratory where the 778 concentrates collected for spectrographic analysis were sieved to minus-30 mesh. Following removal of the light-mineral fraction by flotation in bromoform (specific gravity about 2.8), the heavy-mineral fraction was separated into three splits by electromagnetic separation. The most magnetic fraction contained magnetite and other highly magnetic minerals and rock fragments. The second fraction was of intermediate magnetic susceptibility and consisted of rock fragments as well as most of the more magnetic mafic silicates. The nonmagnetic fraction contained the high-specific-gravity rock-forming minerals such as apatite, zircon, rutile, and sphene, as well as minerals that might indicate alteration and mineralization processes, such as epidote, tourmaline, native gold, fluorite, barite, scheelite, and the sulfide and sulfosalt minerals. This least magnetic fraction of the heavy-mineral concentrate was then split again, if adequate sample was recovered: one portion was used for mineral identification (759 of 778 samples), and a second portion was ground for spectrographic analysis. Out of all samples collected, 721 contained sufficient material for spectrographic analysis.

The minus-80-mesh stream-sediment samples and non-magnetic heavy-mineral-concentrate samples were analyzed by a six-step semiquantitative direct-current-arc emission-spectrographic method (Grimes and Marranzino, 1968). In addition, 140 stream-sediment samples and 551 rock samples were analyzed by atomic-absorption spectrophotometry for gold (Meier, 1980) with a detection limit of 0.002 parts per million (ppm). Another 2,013 rock samples and the 161 unprocessed, bulk panned-concentrate samples were analyzed for gold by an atomic-absorption method with a detection limit of 0.05 ppm (Crock and others, 1987). Data for the latter bulk-concentrate samples, many of which were collected downstream from altered or mineralized outcrops, were converted to μg of gold per pan of collected sample. Geochemical data from the analyses of rock samples collected during geological mapping studies between 1982 and 1986 are tabulated in Wilson and others (1987), and in Angeloni and others (1985). The geochemical data from samples collected during the reconnaissance geochemical survey are tabulated in Arbogast and others (1987).

STATISTICAL SUMMARY

Statistics for the analytical data for the minus-80-mesh stream-sediment samples, nonmagnetic heavy-mineral concentrates, and for gold determined in various sample media are presented in tables 1–3. Many of the elements analyzed were censored, with concentrations for some samples above or below analytical determination limits. Detection ratios, which are calculated as the number of noncensored values divided by the total number of samples analyzed for a given element, describe the degree to which the data are censored. Univariate statistics were computed for those elements with detection ratios greater than 0.10. For tables 1 and 2, the entire data set was used to calculate geometric means, geometric deviations, and percentiles. The G (greater than) values were replaced by values one spectrographic step above the upper determination limits; the L (less than) values were replaced by values one step below the lower determination limits; the N (not detected) values were replaced by values

Table 1. Statistical summary of minus-80-mesh stream-sediment data for the Port Moller, Stepovak Bay, and Simeonof Island quadrangles, Alaska

[Method of analysis: 6-step semiquantitative emission spectrography; values reported in ppm except Ca, Fe, Mg, and Ti (in percent). Au, Sb, W, and Tb not detected. Leaders (--), no meaningful data]

Element	DR[1]	Number of Samples: qualified values[5] N[2]	L[3]	G[4]	Unqualified	Spectrographic determination limits and range of unqual. data: Lower determination limit[6]	Range of values	Upper determination limit[6]	Calculations based on entire data set[7]: Geometric mean	Geometric deviation	Percentile distribution based on entire data set: 50th	85th	95th	97th	99th	Element
Ca	1.00	0	0	0	777	0.05	0.1-5	20	0.81	2.0	1	1.5	2	2	3	Ca
Fe	1.00	0	0	0	777	0.05	0.7-20	20	5.8	1.5	5	10	10	10	15	Fe
Mg	1.00	0	0	0	777	0.02	0.2-7	10	1.5	1.5	1.5	2	3	3	5	Mg
Ti	0.98	0	0	15	762	0.002	0.05-1	1	0.58	1.5	0.5	1	1	1	G	Ti
Ag	0.04	715	35	0	27	0.5	0.5-200	5,000	--	--	N	N	L	0.5	1	Ag
As	0.01	772	0	0	5	200	200-1,500	10,000	--	--	N	N	N	N	N	As
B	0.83	5	127	0	645	10	10-500	2,000	20	2.3	20	50	70	100	150	B
Ba	0.99	0	2	0	775	20	50-1,000	5,000	340	1.7	300	500	700	700	1,000	Ba
Be	0.15	393	271	0	113	1	1-2	1,000	0.48	1.7	N	L	1	1	1	Be
Bi	0.00	775	1	0	1	10	15-15	1,000	--	--	N	N	N	N	N	Bi
Cd	0.00	774	3	0	0	20	--	500	--	--	N	N	N	N	L	Cd
Co	0.99	4	2	0	771	5	5-150	2,000	25	1.7	20	50	50	50	70	Co
Cr	0.99	0	3	0	774	10	10-1,000	5,000	75	2.1	70	150	200	300	500	Cr
Cu	0.99	0	1	0	776	5	5-500	20,000	29	2.1	30	50	70	100	200	Cu
La	0.01	762	5	0	10	20	50-150	1,000	--	--	N	N	N	N	50	La
Mn	0.99	0	0	2	775	10	200-5,000	5,000	910	1.5	1,000	1,000	1,500	2,000	3,000	Mn
Mo	0.09	597	107	0	73	5	5-200	2,000	2.0	1.8	N	L	7	10	20	Mo
Nb	0.00	756	18	0	3	20	20-30	2,000	--	--	N	N	N	N	L	Nb
Ni	0.99	5	3	0	769	5	5-100	5,000	18	1.8	20	30	50	50	70	Ni
Pb	0.86	6	106	0	665	10	10-200	20,000	17	2.0	20	30	50	100	150	Pb
Sc	1.00	0	0	0	777	5	5-50	100	21	1.4	20	30	30	30	50	Sc
Sn	0.00	773	1	0	3	10	10-20	1,000	--	--	N	N	N	N	N	Sn
Sr	0.95	9	24	0	739	100	100-700	5,000	240	1.8	300	500	500	500	700	Sr
V	1.00	0	0	0	777	10	30-1,500	10,000	210	1.7	200	300	500	700	1,000	V
Y	0.99	0	7	0	770	10	10-700	2,000	24	1.6	20	30	50	50	70	Y
Zn	0.11	456	233	0	88	200	200-2,000	10,000	100	1.6	N	L	200	200	500	Zn
Zr	0.99	1	0	0	776	10	10-1,000	1,000	109	1.6	100	200	200	300	500	Zr

[1] Detection ratio (DR) is the number of unqualified values divided by the total number of samples analyzed for a given element.
[2] N is the number of samples in which the element could not be detected at the lower determination limit.
[3] L is the number of samples in which the element could be detected, but which are less than the lower determination limit.
[4] G is the number of samples in which the element could be detected, but which are greater than the upper determination limit.
[5] The qualified population of the data set consists of samples having element concentrations outside of the determination range; coded N, L, or G.
[6] The limits of determination for a given analytical method are the lowest and highest concentrations that can be determined accurately and reported with confidence.
[7] See text for discussion of how the qualified data are handled.

Table 2. *Statistical summary of nonmagnetic heavy-mineral-concentrate data for the Port Moller, Stepovak Bay, and Simeonof Island quadrangles, Alaska*

[Method of analysis: 6-step semiquantitative emission spectrography; values reported in ppm except Ca, Fe, Mg, and Ti (in percent). Leaders (--), no meaningful data]

	Number of Samples					Spectrographic and atomic absorption determination limits and range of unqualified data			Calculations based on entire data set[7]		Percentile distribution based on entire data set					
		Qualified values[5]			Unqualified values	Lower	Range	Upper								
Element	DR[1]	N[2]	L[3]	G[4]		determination limit[6]	of values	determination limit[6]	Geometric mean	Geometric deviation	50th	85th	95th	97th	99th	Element
Ca	0.99	0	8	0	713	0.1	0.1-20	50	1.8	2.9	2	5	10	10	10	Ca
Fe	0.99	0	1	0	720	0.1	0.1-50	50	1.9	3.4	1.5	10	20	30	30	Fe
Mg	0.99	0	2	0	719	0.05	0.05-10	20	0.43	3.0	0.3	1.5	3	5	7	Mg
Ti	0.65	0	0	254	467	0.005	0.1-2	2	1.5	2.1	2	G	G	G	G	Ti
Ag	0.14	594	25	0	102	1	1-3,000	10,000	12	7.2	N	L	20	50	300	Ag
As	0.06	659	16	2	44	500	500-10,000	20,000	--	--	N	N	1,000	1,500	2,000	As
Au	0.03	688	4	4	25	20	20-1,000	1,000	--	--	N	N	N	100	1,000	Au
B	0.87	5	68	18	630	20	20-5,000	5,000	95	3.9	50	500	3,000	5,000	G	B
Ba	0.79	0	13	141	567	50	50-10,000	10,000	900	3.9	1,000	G	G	G	G	Ba
Be	0.03	423	277	0	21	2	2-20	2,000	--	--	N	L	L	L	2	Be
Bi	0.04	675	16	1	29	20	20-2,000	2,000	--	--	N	N	L	30	200	Bi
Cd	0.05	671	16	0	34	50	50-1,000	1,000	--	--	N	N	L	70	200	Cd
Co	0.61	86	196	0	439	10	10-1,000	5,000	31	2.5	10	50	100	150	200	Co
Cr	0.89	19	63	0	639	20	20-2,000	5,000	90	2.6	70	200	500	700	1,000	Cr
Cu	0.65	52	203	0	466	10	10-1,500	50,000	34	3.4	10	100	200	300	700	Cu
La	0.56	268	47	0	406	50	50-2,000	2,000	130	2.0	50	200	300	500	500	La
Mn	0.99	0	1	0	720	20	20-5,000	10,000	460	2.3	500	1,000	2,000	2,000	2,000	Mn
Mo	0.14	519	104	0	98	10	10-200	5,000	22	2.4	N	L	20	50	100	Mo
Nb	0.15	411	205	0	105	50	50-150	5,000	56	1.3	N	L	50	70	70	Nb
Ni	0.30	454	48	0	219	10	10-500	10,000	38	2.5	N	50	100	100	200	Ni
Pb	0.47	211	167	4	339	20	20-20,000	50,000	100	4.7	L	150	1,000	3,000	20,000	Pb
Sb	0.01	709	4	0	8	200	200-1,500	20,000	--	--	N	N	N	N	L	Sb
Sc	0.85	33	61	11	616	10	10-200	200	27	2.1	20	50	100	200	G	Sc
Sn	0.16	527	79	0	115	20	20-2,000	2,000	56	2.8	N	20	70	100	500	Sn
Sr	0.81	83	55	2	581	200	200-10,000	10,000	710	2.0	500	1,000	2,000	3,000	7,000	Sr
Th	0.00	720	1	0	0	200	--	5,000	--	--	N	N	N	N	N	Th
V	0.99	0	4	0	717	20	20-2,000	20,000	113	2.2	100	200	500	500	1,000	V
W	0.04	684	10	0	27	100	100-7,000	20,000	--	--	N	N	L	100	200	W
Y	0.93	14	31	3	673	20	20-3,000	5,000	140	2.8	100	500	1,000	1,500	3,000	Y
Zn	0.19	558	23	5	135	500	500-20,000	20,000	1,400	2.9	N	500	3,000	7,000	15,000	Zn
Zr	0.20	0	1	578	142	20	20-2,000	2,000	2,300	2.1	G	G	G	G	G	Zr

[1] Detection ratio (DR) is the number of unqualified values divided by the total number of samples analyzed for a given element.
[2] N is the number of samples in which the element could not be detected at the lower determination limit.
[3] L is the number of samples in which the element could be detected, but which are less than the lower determination limit.
[4] G is the number of samples in which the element could be detected, but which are greater than the upper determination limit.
[5] The qualified population of the data set consists of samples having element concentrations outside the determination range; coded N, L, or G.
[6] The limits of determination for a given analytical method are the lowest and highest concentrations that can be determined accurately and reported with confidence.
[7] See text for discussion of how the qualified data are handled.

Table 3. Statistical summary of all gold data for the Port Moller, Stepovak Bay, and Simeonof Island quadrangles, Alaska

[Methods of analysis: R (rock samples): quantitative atomic absorption, data in ppm; R1, 0.002 lower determination limit; R2, 0.05 lower determination limit; S (minus-80-mesh stream-sediment samples): quantitative atomic absorption, data in ppm; C (nonmagnetic concentrates): 6-step semiquantitative emission spectrography, data in ppm; BC (bulk concentrates): quantitative atomic absorption, data in micrograms per pan (see text); M (nonmagnetic concentrate remaining after split taken for spectrographic analysis): number of gold flakes noted during microscopic examination. Leaders (--), no data]

Sample type	Number of Samples: Qualified[4] N[1]	L[2]	G[3]	Unqualified	Determination limits and range of unqualified data: Lower determination limit[5]	Range of values	Upper determination limit[5]	Percentile distribution based on entire data set: 50th	75th	85th	90th	95th	97th	99th	Sample type
R1	258	61	0	232	0.002	0.002-4	--	L	0.004	0.012	0.020	0.076	0.15	0.90	R1
R2	1,997	5	0	11	0.05	0.05-0.3	--	N	N	N	N	N	N	N	R2
S	140	17	0	31	0.002	0.002-2.8	--	N	L	0.004	0.035	0.28	0.70	2.0	S
C	688	4	4	25	20	20-1,000	1,000	N	N	N	N	N	100	1,000	C
BC	93	0	0	68	0.3	0.3-6,100	--	N	3.3	11	20	43	80	820	BC
M	737	--	--	22	1	--	--	--	--	--	--	--	--	--	M

[1]N is the number of samples in which gold was not detected at the lower determination limit.
[2]L is the number of samples with detected gold values below the lower determination limit.
[3]G is the number of samples with detected gold values above the upper determination limit.
[4]The qualified population of the data set consists of samples having gold concentrations outside of the determination range; coded N, L, or G.
[5]The limits of determination for gold are the lowest and highest concentrations that can be determined accurately and reported with confidence.

three steps below the lower determination limits. The reliability of mean and deviation values is therefore dependent on how closely the chosen replacement values approximate the actual means of the qualified parts of the data set for each element; reliability also depends on the detection ratio for that element. Minimum, 50th, 85th, 95th, 97th, and 99th percentile, and maximum values were tabulated to show the distribution of geochemical data. Geometric means and deviations were not calculated for gold data in table 3 because of low detection ratios for the R2 rock samples and the nonmagnetic heavy-mineral concentrate samples. Means and deviations were also not calculated because the R1 rock samples, stream-sediment samples, and bulk-concentrate samples analyzed by atomic-absorption methods are biased samples collected primarily from mineralized areas.

Anomalous element values are those that stand out above some geochemical background. Commonly in geochemical studies, the 95th percentile for a given geochemical distribution is chosen as a geochemical threshold: all values greater than that threshold are considered to be anomalous. The 95th percentile values for all analyzed elements are listed in tables 1–3. However, for many elements, the reader may wish to adjust geochemical thresholds up or down from the 95th percentile to accommodate distinct breaks in the frequency distribution of the data. Therefore, bar diagrams have been included that show elemental distributions for selected analytical data (figs. 2 and 3). The anomaly thresholds chosen for selected elements detected in stream-sediment samples (Frisken and Arbogast, 1991a) are shown in table 4, and those for selected elements detected in nonmagnetic heavy-mineral concentrates (Frisken and Arbogast, 1991b) are shown in table 5. Rock-sample anomaly thresholds for copper (150 ppm) and molybdenum (5 ppm) are chosen at the 97th and 95th percentile, respectively (calculated from data in Angeloni and others, 1985; Arbogast and others, 1987; and Wilson and others, 1987). Except for gold data from nonmagnetic heavy-mineral-concentrate samples, thresholds for gold cannot be accurately determined by the above procedure because samples selected for low-level atomic-absorption analysis were primarily collected from areas of mineralized rocks.

Geologic mapping in the study area (Wilson and others, in press) forms the geologic framework for geochemical interpretations. A simplified geologic map of the study area is shown on plate 3 and is from Wilson and others (1991). This map is also used as a base for figures 4–6, which are referenced in the interpretive discussions that follow.

FACTOR ANALYSIS METHODS

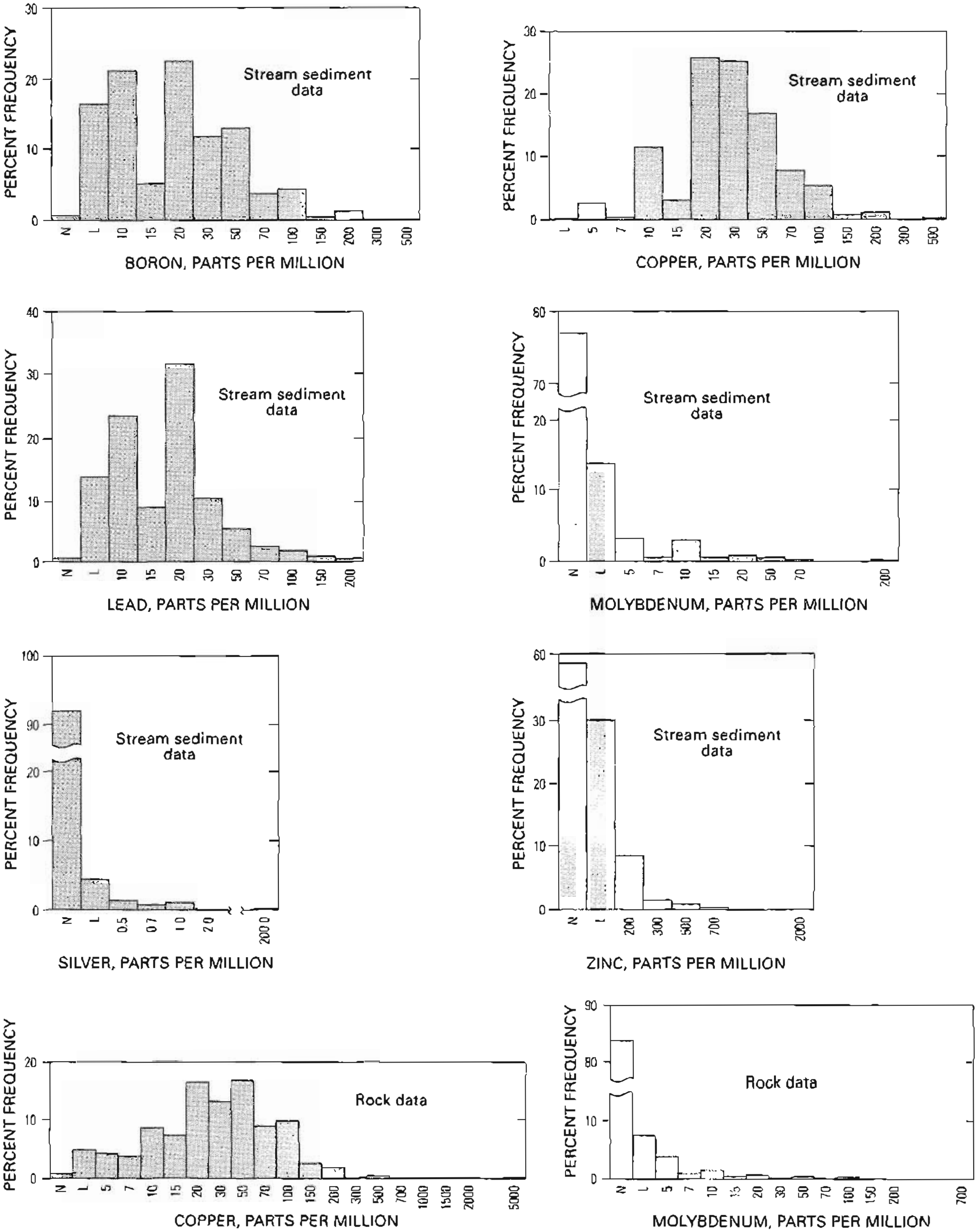
R-mode factor analysis with Varimax rotation was used to identify the dominant geochemical associations in log-transformed stream-sediment and nonmagnetic heavy-mineral concentrate data sets. Prior to log transformation, several highly censored elements were removed from each database: all elements having detection ratios less than 0.80 were removed from the stream-sediment data matrix; for the nonmagnetic heavy-mineral-concentrate data, elements having detection ratios less than 0.30 were removed—however, some highly censored elements (silver, molybdenum, tin, and zinc) that are common pathfinders for various mineral-resource types were retained. A series of analyses, both with and without these four highly censored elements, showed that inclusion of these elements caused virtually no change in the other variable correlations. Inclusion of these censored elements provides a quick means for identifying correlations within the upper ends of their distributions.

Factor analysis places elements with like behavior into groups termed factors. Specific lithologies or ore-deposit types may be defined by a distinct suite of trace elements, and, therefore, certain factors can be used to definne common geochemical signatures in a study area. Factor loadings for the stream-sediment and nonmagnetic heavy-mineral-concentrate data sets are listed in tables 6 and 7. The factor loadings, which depict the influence of each variable on a factor, may be interpreted similarly to correlation coefficients. The optimal number of factors chosen from each data matrix, discussed below, was based on breaks in slope on plots of factor number versus total variance. Factor scores for each sample on each factor measure the contribution of that factor for each individual sample. The 0–2.5, 90–97.4, 97.5–98.9, and 99–100 percentile ranges of factor scores for the two data sets were plotted and examined. The 0–2.5 percentile range was included to better understand the nature of samples representing each factor. Samples with the lowest factor scores are least representative of that factor and may suggest, for example, a lithological control if factor scores are highest for samples collected from areas underlain by granite and lowest for samples collected from areas underlain by basalt.

SEDIMENT-SAMPLE FACTOR-ANALYSIS ASSOCIATIONS

A five-factor model that explains 71 percent of the total variance was selected to summarize the stream-sediment

Figure 2 (facing page). Bar diagrams showing distribution of selected data for minus-80-mesh stream-sediment samples and for copper and molybdenum in rock samples. N is the number of samples in which the element could not be detected at the lower determination limit; L is the number of samples in which the element was detected but at concentrations below the lower determination limit; and G is the number of samples in which the element was detected at concentrations above the upper determination limit.


PERCENT FREQUENCY
Stream sediment data
BORON, PARTS PER MILLION
COPPER, PARTS PER MILLION
LEAD, PARTS PER MILLION
MOLYBDENUM, PARTS PER MILLION
SILVER, PARTS PER MILLION
ZINC, PARTS PER MILLION
Rock data
COPPER, PARTS PER MILLION
MOLYBDENUM, PARTS PER MILLION

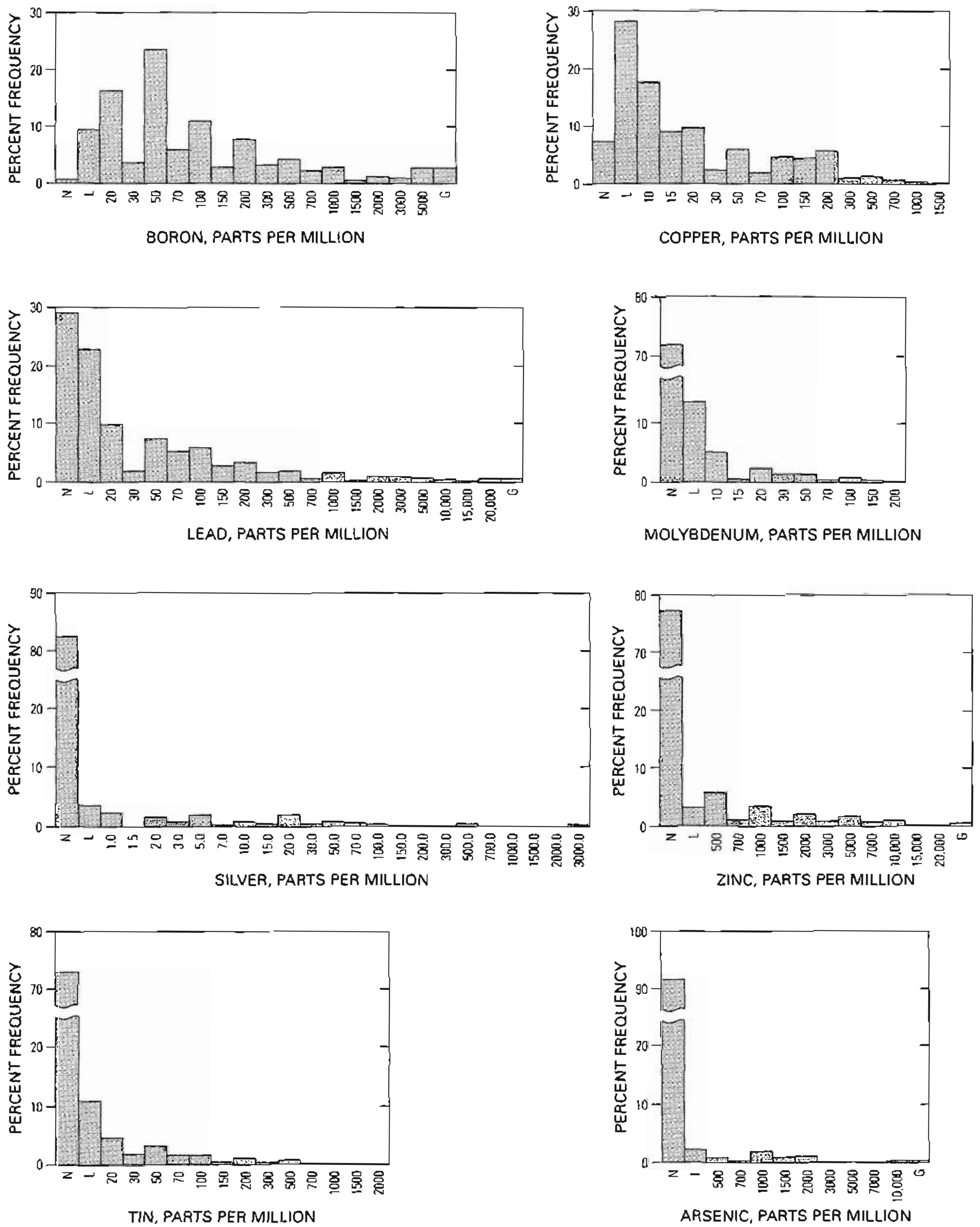
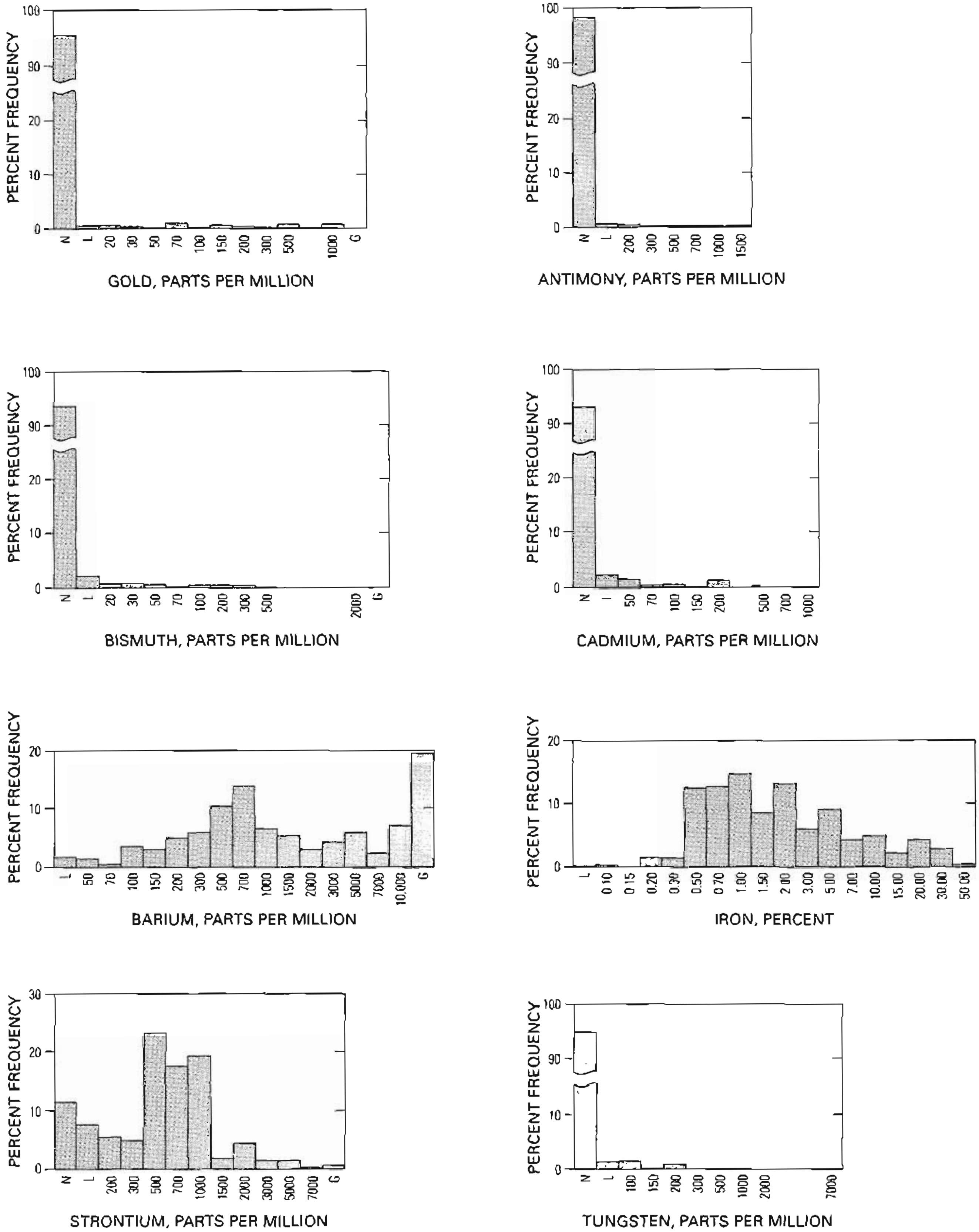


Figure 3 (above and facing page). Bar diagrams showing distribution of selected data for nonmagnetic heavy-mineral-concentrate samples. N is the number of samples in which the element could not be detected at the lower determination limit;



L is the number of samples in which the element was detected but at concentrations below the lower determination limit; and G is the number of samples in which the element was detected at concentrations above the upper determination limit.

Table 4. Chosen thresholds and corresponding percentiles for selected elements in stream-sediment samples

Element	Threshold[1] (ppm)	Percentile
Ag	L(0.5) ppm	92
As	200 ppm	99
B	70 ppm	90
Cu	70 ppm	85
Mo	5 ppm	91
Pb	50 ppm	89
Sn	L(10) ppm	99
Zn	200 ppm	89

[1]The threshold value is the lowest value considered to be anomalous. The thresholds assigned for Ag, As, and Sn are equal to the lowest detected values. (L indicates the specific element was detected but at concentrations below the lower determination limit).

data. Four of the factors are apparently related to lithology, but one stream-sediment factor (SSF–4, table 6) indicates areas of mineralized rock.

The first factor (SSF–1) shows high positive loadings for the mafic elements iron, vanadium, and titanium; it shows somewhat lower loadings for cobalt, manganese, magnesium, chromium, and scandium and shows a weak negative loading for boron (table 6). Samples with high SSF–1 factor scores are dominated by dark mafic minerals. The SSF–1 factor therefore represents high concentrations of magnetite, ilmenite, amphiboles, and pyroxenes, all of which were probably derived from mafic rocks. Most samples with high SSF–1 scores were collected from areas on the Shumagin Islands that are underlain by the Popof volcanic rocks.

The second factor (SSF–2) has high positive loadings for barium and zirconium and somewhat lower loadings for yttrium, boron, and lead (table 6). Although the SSF–2 factor has high positive loadings for elements characteristic of felsic rocks, the granodioritic Shumagin Islands batholith is not delineated by this factor. Many of the samples with high SSF–2 scores are from drainage basins underlain by the Bear Lake Formation, which contains clasts of granite. The factor probably represents barium-rich feldspar, or barite and zircon weathered from various rock units.

The third factor (SSF–3) has high positive loadings for the mafic elements nickel and chromium and somewhat lower loadings for cobalt and scandium (table 6). Samples with high SSF–3 scores are scattered throughout the Port Moller study area, though many of these samples represent drainage basins underlain by the Hoodoo Formation or by the Popof volcanic rocks in the northeastern part of Popof Island.

The fourth factor (SSF–4) has high positive loadings for copper, lead, and boron (fig. 4, table 6). Most samples with high SSF–4 scores were collected from areas of mineralized and altered clastic or volcanic rocks associated with hypabyssal intrusive rocks of intermediate composition. These areas of mineralized rocks typically show stream-sediment geochemical anomalies for copper, molybdenum, silver, lead, and zinc, and less frequently for boron, tin, and arsenic. Frisken and Arbogast (1991a) delineate 14 areas of highly anomalous stream-sediment geochemical values. Twelve of these areas are also represented by most of the high SSF–4 scores. From west to east on the mainland, these 12 areas include: (1) the Canoe Bay gold prospect located between Mount Dana and Canoe Bay, (2) the Four Bear Creek area located between Mount Dana and Hoodoo Mountain, (3) the Beaver River drainage basin, (4) the Pyramid porphyry copper prospect, and (5) the San Diego Bay porphyry copper prospect area, located between Albatross Anchorage, Dorenoi Bay, and San Diego Bay. To the north and northwest, areas include (6) an area between Mud Bay and Grass Valley, (7) the Mount Stepo area, and (8) the peninsula northwest of Grub Gulch. On offshore islands, from west to east, areas include (9) northwestern Dolgoi Island, (10) southeastern Unga Island, (11) south-central Popof Island, and (12) central Nagai Island

Of the nine sites with high SSF–4 scores that are not located within the above 12 areas, four sites are adjacent to and downstream from the Four Bear Creek area and one site with

Table 5. Chosen thresholds and corresponding percentiles for selected elements in nonmagnetic heavy-mineral-concentrate samples

Element	Threshold[1] (ppm)	Percentile
Ag	L(1) ppm	82
As	L(500) ppm	91
Au	L(20) ppm	95
B	1,500 ppm	93
Ba	G(10,000) ppm	80
Bi	L(20) ppm	94
Cd	L(50) ppm	93
Cu	150 ppm	86
Fe	20 percent	92
Mo	10 ppm	86
Pb	150 ppm	84
Sb	L(200) ppm	98
Sn	30 ppm	89
Sr	2,000 ppm	92
W	L(100) ppm	88
Zn	700 ppm	86

[1]The threshold value is the lowest detectable value considered to be anomalous. The threshold values assigned for Ag, As, Au, Bi, Cd, Sb, and W are their lowest detected value. (L indicates the specific element was detected but at concentrations below the lower determination limit; G indicates concentrations above the upper determination limit).

a very high SSF–4 score lies on the north side of Andronica Island. Samples collected at the latter site are collectively anomalous in copper, lead, zinc, nickel, cobalt, barium, arsenic, boron, and manganese. A site with a slightly high SSF–4 score occurs on a tributary of Driftwood Creek in the northwestern corner of the study area. There, a stream-sediment sample contained anomalous concentrations of copper and zinc, and, nearby, disseminated sulfides occurred in sandstone that contained anomalous concentrations of molybdenum, zinc, and arsenic. No intrusive or volcanic rocks were noted in this area. Two other sites with slightly high SSF–4 scores lie northwest of Grub Gulch along the north side of the Aleutian Range. The rocks at these locations are propyliticalJy altered and contain abundant disseminated and vein pyrite. Stream-sediment, concentrate, and rock samples collected at the two sites collectively contain anomalous concentrations of copper, molybdenum, lead, zinc, nickel, cobalt, and arsenic. The final site with a slightly high SSF–4 score is located north of Herring Lagoon in the northeastern corner of the study area. Samples of fine-grained intrusive(?) rocks and contact-metamorphosed sedimentary rocks collected from this area collectively contain anomalous concentrations of gold, silver, and boron.

The fifth factor (SSF–5) has high positive loadings for calcium, strontium, scandium, and magnesium and somewhat lower loadings for yttrium, manganese, and cobalt

Table 6. Factor loadings for the first five factors after Varimax rotation of log-transformed analytical data from stream-sediment samples

[Total variance explained by five factors equals 71 percent. DR, detection ratio. Leaders (--), loadings less than |0.3|]

Element	DR	"Stream-sediment factors" (SSF) 1	2	3	4	5
B	0.83	-0.37	0.40	--	0.58	--
Ba	.99	--	.82	--	--	--
Ca	1.0	--	--	--	--	0.82
Co	.99	.55	--	0.51	--	.36
Cr	.99	.37	--	.78	--	--
Cu	.99	--	--	--	.78	--
Fe	1.0	.86	--	--	--	--
Mg	1.0	.48	--	--	--	.64
Mn	.99	.51	--	--	--	.41
Ni	.99	--	--	.88	--	--
Pb	.86	--	.37	--	.70	--
Sc	1.0	.37	--	.36	--	.65
Sr	.95	--	--	--	--	.74
Ti	.98	.72	.32	--	--	--
V	1.0	.83	--	--	--	--
Y	.99	--	.56	--	--	.52
Zr	.99	--	.81	--	--	--
Percent of total variance explained by the factor		30	14	12	8	7

(table 6). Samples with high SSF–5 scores are scattered throughout the study area and do not appear to represent a particular geologic environment.

CONCENTRATE-SAMPLE FACTOR-ANALYSIS ASSOCIATIONS

The six-factor model chosen to reduce the nonmagnetic heavy-mineral-concentrate data explains 71 percent of the total variance. The first nonmagnetic heavy-mineral-concentrate factor, or "panned-concentrate factor," (PCF–1) has high positive loadings for iron, cobalt, nickel, and copper and somewhat lower loadings for zinc, lead, barium, and molybdenum (fig. 5, table 7). The nonmagnetic heavy-mineral concentrates with high PCF–1 factor scores contain a very high percentage of pyrite, considerable barite, and lesser amounts of sphalerite, galena, molybdenite, chalcopyrite, and cinnabar. Quartz and pyrite veins, red color anomalies, and quartz diorite were noted in outcrop or stream cobbles near most of these sites. This factor identifies concentrates rich in base-metal sulfides and shows a distribution similar to that of SSF–4. All but three of the concentrates with high PCF–1 factor scores plot within areas of nonmagnetic heavy-mineral concentrate anomalies delineated by

Table 7. Factor loadings for the first six factors after Varimax rotation of log-transformed analytical data from nonmagnetic heavy-mineral-concentrate samples

[Total variance explained by five factors equals 71 percent. DR, detection ratio. Leaders (--), loadings less than |0.3|]

Elements	DR	"Panned-concentrate factors" (PCF) 1	2	3	4	5	6
Ag	0.14	--	--	--	--	0.79	--
B	.87	--	--	0.30	0.32	--	0.51
Ba	.79	0.40	-0.32	--	.68	--	--
Ca	.99	--	.84	--	--	--	--
Co	.61	.89	--	--	--	--	--
Cu	.65	.82	--	--	--	--	--
Cr	.89	--	.36	--	--	--	.73
Fe	.99	.89	--	--	--	--	--
La	.56	--	--	.80	--	--	--
Mg	.99	--	.73	--	--	--	.54
Mn	.99	--	.79	.31	--	--	--
Mo	.14	.34	-0.44	--	--	--	--
Ni	.30	.86	--	--	--	--	--
Pb	.47	.44	--	--	--	.63	--
Sc	.85	--	.33	.55	--	--	.44
Sn	.16	--	--	--	-0.35	.54	.31
Sr	.81	--	--	--	.83	--	--
Ti	.65	--	--	.70	--	--	.48
V	.99	--	--	--	--	--	.78
Y	.93	--	--	.84	--	--	--
Zn	.19	.49	--	--	--	.42	--
Percent of total variance explained by the factor		22	21	10	7	6	5

Frisken and Arbogast (1991b). Most concentrate samples with high PCF–1 scores surround the Ivanof porphyry copper prospect, located east of Ivanof Bay in the northeastern part of the study area. This area, characterized by molybdenite in nonmagnetic heavy-mineral concentrates, was not delineated by SSF–4 sediment-factor scores. Other samples with high PCF–1 scores occur in the Grub Gulch, Mud Bay, San Diego Bay, Pyramid Mountain, and Beaver River areas. Most known mineralized areas, and the porphyry copper-molybdenum systems in particular, are delineated by this factor. Concentrate samples collected near the Apollo gold mine and zones of mineralized rocks on Dolgoi, Mitrofania, and the central Shumagin Islands are not represented by anomalous PCF–1 scores.

The second factor (PCF–2) has high positive loadings for calcium, manganese, and magnesium, somewhat lower loadings for chromium and scandium, and weak negative loadings for barium and molybdenum (table 7). Nonmagnetic heavy-mineral concentrates with high PCF–2 scores are rich in feldspars, amphiboles, or pyroxenes: these minerals are not, however, typically found in heavy-mineral concentrate fractions. The presence of these minerals in heavy-mineral-concentrate samples is likely due to poor quality bromoform or magnetic separations of some concentrate samples. Most of these samples were too small in volume to undergo further separations.

The third factor (PCF–3) has high positive loadings for yttrium, lanthanum, and titanium and somewhat lower loadings for scandium, manganese, and boron (table 7). This factor probably represents granitic rocks or sedimentary rocks derived, in part, from a granitic source. The nonmagnetic heavy-mineral concentrates with high PCF–3 factor scores

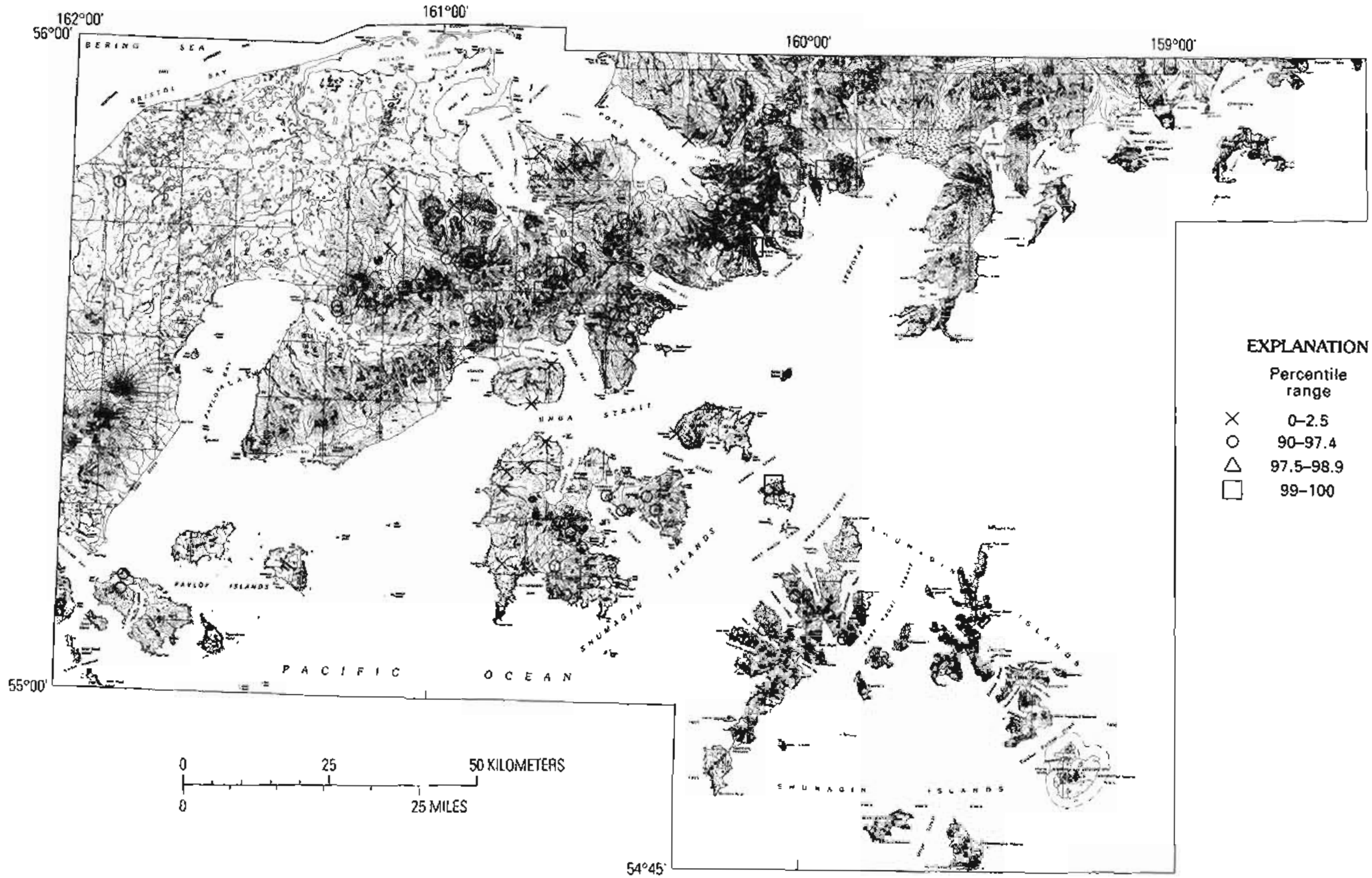


Figure 4. Distribution of selected factor scores for stream-sediment factor 4 (SSF–4). Factor has high positive loadings for copper, lead, and boron. The area shown on this figure is shown at a larger scale on plates 1–3.

contain abundant zircon; the titanium mineral anatase (octahedrite) was noted in some samples. Zirconium was deleted from the database because most of the nonmagnetic heavy-mineral-concentrate values for zirconium were above the upper determination limit. Most sites with high PCF–3 scores are in the outer Shumagin Islands: an area underlain primarily by granodiorite of the Shumagin Islands batholith. Most of the other high-score sites lie between Canoe Bay and Port Moller Bay: a region dominated by siltstone, sandstone, and some conglomerate. Other sites with high PCF–3 scores lie between the Ivanof porphyry copper prospect and Mitrofania Island. Sites with low PCF–3 scores occur in the eastern half of Popof Island and surround Pavlof Volcano; both areas are dominated by mafic volcanic rocks.

The fourth factor (PCF–4) has high positive loadings for strontium and barium, a somewhat lower loading for boron, and a weak negative loading for tin (table 7). The nonmagnetic heavy-mineral concentrates with high PCF–4 scores are rich in barite and (or) celestite. Most of the sites with high PCF–4 scores are underlain by marine sedimentary rocks, especially the area within and to the west and east of the Beaver River drainage—this area is dominated by siltstone, sandstone, and black shale. Areas with very low PCF–4 scores occur at the Ivanof porphyry copper prospect and in the outer and central Shumagin Islands (excluding the northern end of Nagai Island).

The fifth factor (PCF–5) has high positive loadings for silver and lead and somewhat lower loadings for tin and zinc (fig. 6, table 7). Examination of single-element anomaly maps for silver, gold, and antimony in nonmagnetic heavy-mineral concentrates shows that there is a good correlation between these three elements. This correlation suggests that, were they not highly censored, gold and antimony would also fall into concentrate factor 5 (PCF–5). Nonmagnetic heavy-mineral concentrates with high scores for this precious-metal factor contain sulfides but do not contain as much pyrite as do the nonmagnetic heavy-mineral concentrates that represent the base-metal factor (PCF–1). Sites represented by high PCF–5 factor scores are located around the following areas: the Apollo gold mine, the area of placer gold mining in the southwestern part of Popof Island, the northeast coast of Unga Island, northwestern Dolgoi Island, the upper Beaver River drainage basin, the west side of the peninsula east of Grub Gulch, and the Ivanof porphyry copper prospect.

The sixth factor (PCF–6) has high positive loadings for vanadium and chromium, and somewhat lower loadings for magnesium, boron, titanium, scandium, and tin (table 7). Many of the nonmagnetic heavy-mineral concentrates with high PCF–6 factor scores were collected in areas of pyrite-rich altered rocks or in areas of gossen or iron-oxide-stained rocks. Most areas of highly altered or pyrite-rich rocks are not, however, indicated by this factor. Most of the sites with high PCF–6 scores are in areas underlain by Tertiary volcanic rocks, especially in the southeastern half of Unga Island, on Popof and Dolgoi Islands, around the San Diego Bay porphyry copper prospect, and on the Kupreanof Peninsula.

DISCUSSION OF MINERAL OCCURRENCES AND GEOCHEMICAL ANOMALIES

Within the Port Moller study area, conspicuous geochemical anomalies all appear to be related to areas of hydrothermally altered and mineralized clastic or volcanic rocks and are usually spatially associated with hypabyssal intrusive rocks of intermediate composition. Known mineral occurrences in the study area include porphyry copper and molybdenum deposits and base- and precious-metal vein deposits. Other types of mineral or energy resources could exist within the geologic environment of the Port Moller study area, but none were suggested by geochemical methods during the present study. A non-economic occurrence of sulfur deposited around fumaroles is located at an elevation of about 900 m at the head of the main river draining into Ramsey Bay (Wilson and others, 1988). During the present study, sulfur was also noted in stream cobbles collected from the upper Milky River drainage basin, from the head of Grub Gulch, and from the east side of the Big River drainage basin. Small quantities of coal have been mined on Unga Island and on the peninsula between Herendeen Bay and Port Moller Bay (Atwood, 1911). Scintillometer readings were made at most sample sites, and eight rock samples were collected for uranium analyses from sites that had readings of two to three times background. These samples were not found to contain anomalous concentrations of uranium. In addition, no anomalous concentrations of thorium were obtained from any of the 2,263 spectrographic analyses done on stream-sediment, nonmagnetic heavy-mineral-concentrate, or rock samples.

Geochemically anomalous areas, which are thought to indicate the most favorable ground for porphyry copper-molybdenum-type deposits or base- and precious-metal vein systems, are outlined on maps for stream-sediment data (Frisken and Arbogast, 1991a) and nonmagnetic heavy-mineral-concentrate data (Frisken and Arbogast, 1991b) and are shown on maps for gold data from all sample media (Frisken and Kelley, 1991).

In this report, maps showing the distribution of scores for factors related to mineralization are shown in figures 4–6, and the distribution of anomalous gold concentrations, determined from stream-sediment, panned-concentrate, and rock samples, is shown on plate 1. Plate 2 shows sites that have stream-sediment, nonmagnetic heavy-mineral-concentrate, or rock samples that contain anomalous concentrations of copper and (or) molybdenum. These sites are generally surrounded by drainage basins that contain anomalous concentrations of copper, lead, zinc, silver, gold, tin, arsenic, antimony, bismuth, tungsten, cadmium, iron, boron, barium, or strontium, and they are interpreted as centers of porphyry

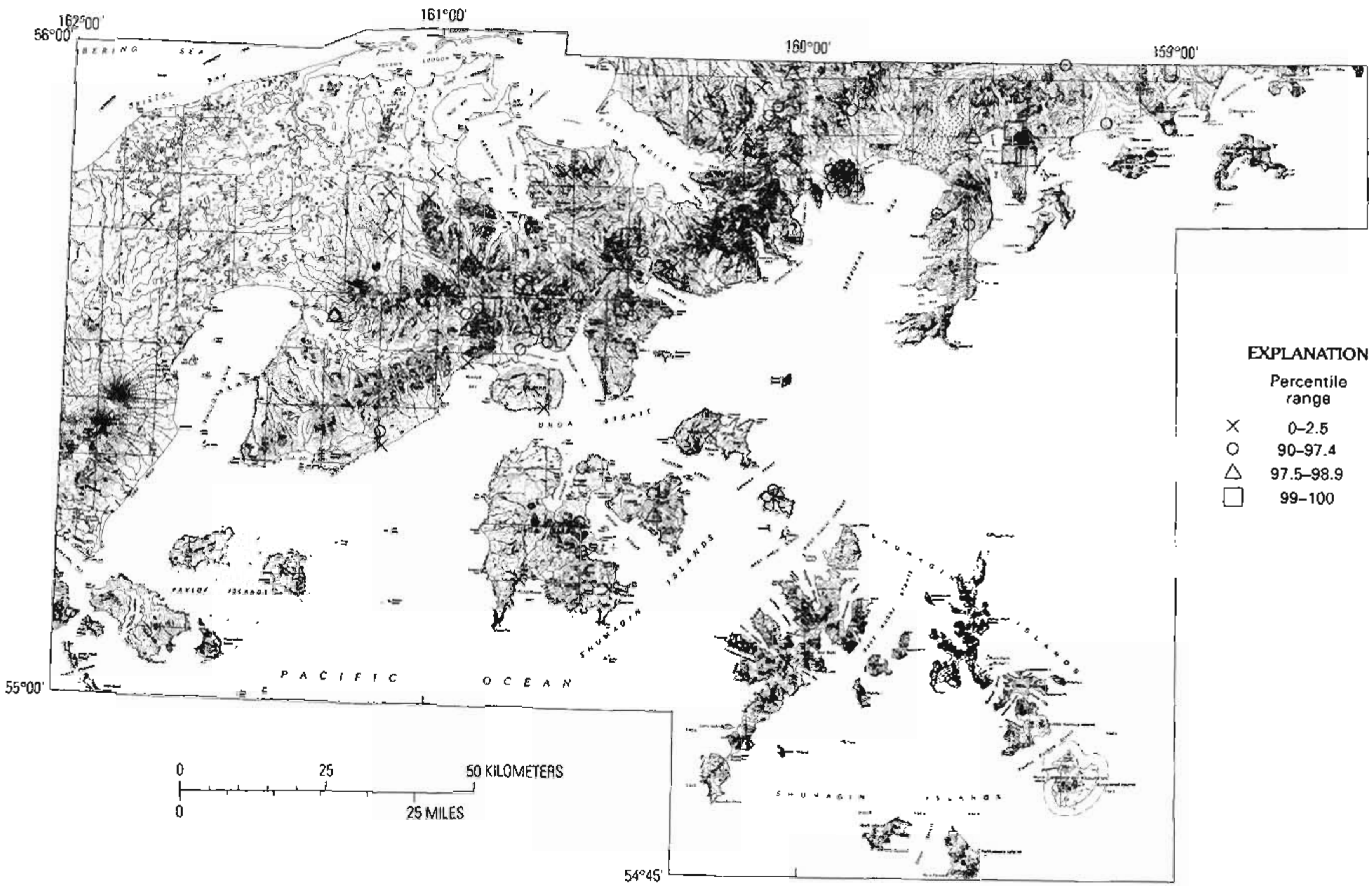


Figure 5. Distribution of selected factor scores for heavy-mineral-concentrate factor 1 (PCF–1). Factor has high positive loadings for iron, cobalt, nickel, and copper and somewhat lower positive loadings for zinc, lead, barium, and molybdenum. The area shown on this figure is shown at a larger scale on plates 1–3.

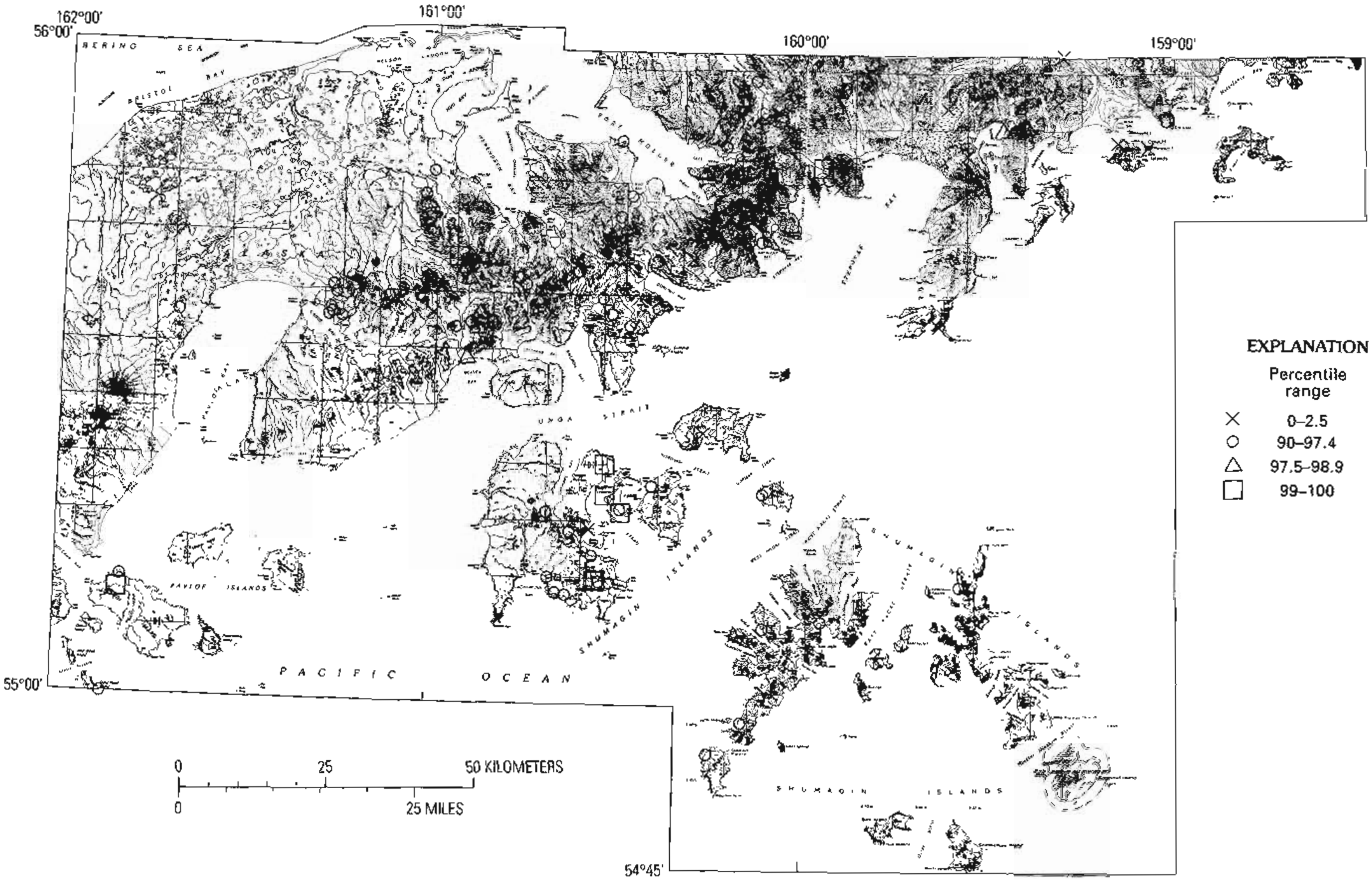


Figure 6. Distribution of selected factor scores for nonmagnetic heavy-mineral-concentrate factor 5 (PCF–5). Factor has high positive loadings for silver and lead and somewhat lower positive loadings for tin and zinc. The area shown on this figure is shown at a larger scale on plates 1–3.

copper-molybdenum-type mineralization, possibly surrounded by base- and (or) precious-metal veins.

DESCRIPTION OF GOLD ANOMALIES

Plate 1 shows the distribution of gold within the study area, as determined from rock, stream-sediment, bulk panned-concentrate, and nonmagnetic heavy-mineral-concentrate samples. The choice of threshold values used to define anomalies for the various sample media is complicated by several factors. The 140 stream-sediment and 551 rock samples analyzed by the atomic-absorption method with a 0.002 ppm determination limit, in addition to the bulk panned-concentrate samples, were primarily collected from areas known to be mineralized and are therefore biased samples. In addition, the acid digestion used in the atomic-absorption methods attacks primarily nonsilicate minerals present in the sample. Most detectable gold is, therefore, thought to be introduced by mineralization processes. The lowest detectable atomic-absorption gold values may or may not be anomalous. Numerous gold values that were detected (but at levels slightly below the 0.002 ppm lower determination limit) in stream-sediment samples and rock samples (below 0.004 ppm) most likely represent background concentrations and are not plotted. In the bulk panned-concentrates, detectable gold values presumably represent at least minimum values for the original concentration of gold in each pan of collected sediment. The finest grained gold dust, known as flour gold, can float on water and, if present in the sediment, can be lost in the panning process. For example, 10 μg of gold determined in a bulk-concentrate sample could represent the weight of a single flake of flour gold.

The samples indicated by solid symbols on plate 1 contain gold concentrations above the 95th percentile for the large data sets that represent 2,564 rock samples and 721 nonmagnetic heavy-mineral concentrates. The smaller, biased, bulk panned-concentrate and stream-sediment data sets are subdivided at the 85th percentile; the solid symbols on plate 1 represent gold concentrations above the 85th percentile.

Nineteen areas of clustered gold anomalies that appear to be most significant are numbered and delineated by solid lines on plate 1 and are discussed below. Areas with past gold production or that presently have proven reserves are limited to area 1 in the southeastern part of Unga Island and to beach placer deposits along the southwest coast of Popof Island, located in area 4 (plate 1). Plate 1 shows that gold is widely distributed in the Port Moller study area. Many of the highest gold concentrations were obtained from samples collected on Unga and Popof Islands. Most of the gold values that fall within areas delineated by dashed lines on plate 1 are associated with an abundance of other metal anomalies in stream-sediment and nonmagnetic heavy-mineral-concentrate samples (Frisken and Arbogast, 1991a, 1991b). These anomalies include some combination of the elements copper, molybdenum, silver, lead, zinc, boron, tin, arsenic, antimony, bismuth, gold, strontium, cadmium, iron, tungsten, and barium or are indicated by the presence of visually identified chalcopyrite, molybdenite, gold, galena, pyrite, scheelite, powellite, celestite, barite, fluorite, or cinnabar.

Most of the gold detected in rocks is associated with anomalous concentrations of silver, copper, lead, zinc, arsenic, antimony, or bismuth. The highest gold values in rocks, which range from 1.2 to 9.5 ppm, were determined from epithermal quartz-sulfide vein samples collected on southeastern Unga Island, western Mitrofania Island, and along the west side of Kuiutka Bay in the northeastern corner of the study area. Gold values determined in stream-sediment and panned-concentrate samples that were among the most anomalous were from samples collected from southeastern Unga Island, southwestern Popof Island, the Canoe Bay gold prospect, the Four Bear Creek drainage basin, the upper Canoe Bay River drainage basin, the drainage basins immediately north of the Four Bear Creek and Canoe Bay River drainage basins, the middle and lower Beaver River drainage basin, and the San Diego Bay porphyry copper prospect.

Southeastern Unga Island, including areas 1 and 2 (plate 1), is underlain in part by andesitic, dacitic, and tuffaceous rocks of the Popof volcanic rocks that have been locally intruded by Tertiary intrusive bodies. The rocks have undergone extensive propylitic alteration. Local argillic and sericitic alteration has occurred along fracture zones, especially in areas of permeable rocks. Silica flooding along generally northeast-trending fault zones has formed numerous epithermal quartz veins, some of which are enriched in base and (or) precious metals. Quartz veins are best developed where fracture zones cut competent flow rocks and are poorly developed in areas of flow breccia and volcaniclastic rocks. The veins vary in width and length and represent multiple periods of fracturing, brecciation, and silicification (B.M. Gamble, written commun., 1983). Primary ore minerals are native gold, electrum, galena, sphalerite, and chalcopyrite. Because the gold is primarily microscopic and is therefore easily lost during the panning process, gold values determined by atomic-absorption analysis of stream-sediment and rock samples best delineate the distribution of gold on Unga, Popof, Korovin, and Andronica Islands, where all stream-sediment samples have been analyzed for gold by atomic absorption.

In area 1 (plate 1), no bulk concentrates were collected and gold was detected in only three nonmagnetic heavy-mineral concentrates. Gold values as high as 0.15 ppm were detected in 19 of 26 stream-sediment samples collected in or adjacent to area 1, and 12 of the rock samples collected in area 1 have gold concentrations ranging from 0.05 to 9.5 ppm. The samples with the highest gold concentrations were collected from quartz-sulfide veins at the Sitka mine and Shumagin gold deposit. At least 20 mines, prospects, or mineral occurrences are located within or adjacent to area 1 (Wilson and others, 1988) and probably account for most of the geochemical anomalies in the vicinity of area 1.

Area 2 (plate 1) lies in the east-central part of Unga Island and is underlain by the Popof volcanic rocks, clastic rocks of the Unga Formation, and Tertiary intrusive bodies. Five precious- and base-metal prospects and occurrences are located in area 2 (Wilson and others, 1988). Quartz veins, quartz dioritic intrusive rocks, and red color anomalies were noted in area 2, and three altered andesite samples and one quartz diorite sample had gold concentrations ranging from 0.032 to 0.15 ppm. Gold was seen in a nonmagnetic heavy-mineral-concentrate sample collected on the east side of the ridge southeast of the head of Zachary Bay. Gold was detected (3 and 4 µg/pan) in bulk-concentrate samples collected from two drainage basins that drain the area of the Thormac prospect, which is located about 5 km southeast of the head of Zachary Bay. Eight of 13 stream-sediment samples collected in area 2 had gold concentrations ranging from less than 0.002 to 2.4 ppm. The most anomalous samples were collected from a small tributary drainage basin immediately south of the Thormac prospect (0.25 ppm) and from a small tributary drainage basin 3 km south of the head of Zachary Bay on the west side of a large valley (2.4 ppm).

Area 3 (plate 1) lies in the northeastern part of Unga Island and is underlain by the Popof volcanic rocks. Gold concentrations of 0.002, 0.006, and 0.012 ppm were determined in iron-oxide-stained andesite samples collected along Zachary Bay. Mercury values of 0.06, 2.8, and 0.16 ppm also occurred in these rocks. Abundant cinnabar was seen in a nonmagnetic heavy-mineral concentrate collected from the largest stream draining area 3, but the stream-sediment sample collected there did not contain detectable gold. Only four other samples from sites in the study area contained two or more grains of cinnabar in nonmagnetic heavy-mineral concentrates, although mercury concentrations ranging from 0.1 to 15 ppm were common in analyzed pyrite or iron-oxide-rich volcanic rocks collected from many parts of the study area. A nonmagnetic heavy-mineral concentrate collected south of West Head contained 20 ppm gold and 20 ppm silver; the stream-sediment sample from this same site contained 0.3 ppm gold.

Area 4 (plate 1) includes most of the central and southwestern parts of Popof Island. A small inactive placer gold mine, three prospects, and two mineral occurrences lie on Popof Island along the northeasterly trend of faults mapped on both Unga and Popof Islands. The Mary Lou (Sand Point) placer deposit (Atwood, 1911) was exploited in 1904 and 1905. An estimated 3,000 to 4,000 oz of gold (B.S. Webber, J.M. Moss, F.A. Rutledge, and R.S. Sanford, U.S. Bureau of Mines, written commun., 1946) was recovered from beach sand and gravel, mostly around boulders near the low-tide mark. Additional placer gold concentrations may occur seaward of the present-day low-tide line. The gold was eroded from a mineralized area that includes the Herman Lode prospect, located in the cliffs above the beach placers. Gold, galena, chalcopyrite, and sphalerite are reported to occur at this prospect in quartz veins hosted by andesite and tuff (B.S. Webber, J.M. Moss, F.A. Rutledge, and R.S. Sanford, U.S. Bureau of Mines, written commun., 1946). Small intrusive bodies and altered rocks of the Popof volcanic rocks and clastic rocks of the Stepovak Formation occur in area 4. Zones of alteration show red color anomalies, quartz veins, argillically altered rocks, and altered quartz-rich intrusive(?)rocks. Several rock samples collected within area 4 contained anomalous gold concentrations. The highest gold concentrations occur in three quartz vein samples (0.1 ppm) and four altered andesite(?) samples (0.04–0.9 ppm). The highest gold concentration was determined from a pyrite-rich andesite sample collected from the south-central part of the island, east of Red Cove. Sphalerite was abundant in the nonmagnetic heavy-mineral concentrate collected downstream from this site. Most gold anomalies occur in the southwestern part of the island between Sand Point and Red Cove. Geochemically anomalous samples collected at a site west of the airport at Sand Point were beach sediments and pebbles that may have been transported by longshore currents—the nonmagnetic heavy-mineral concentrate collected at this site contains more than 1,000 ppm gold and 1,500 ppm silver. Several flakes of gold were identified in two nonmagnetic heavy-mineral concentrates collected from a small drainage basin located about 4 km southeast of Sand Point along the southwest coast of the island. Gold was detected in stream-sediment samples from the south coast of the island at Sand Point (1 ppm), 4 km southeast of Sand Point (1.2 ppm), and east of Red Cove (0.002 ppm).

Area 5 (plate 1) includes the Canoe Bay gold prospect, where Freeport Exploration Company found as much as 415 ppm of fine-grained gold in panned-concentrate samples (Wilson and others, 1988). Nokleberg and others (1987) describe the Canoe Bay prospect as a gold-bearing quartz-cemented breccia with gold in altered late Tertiary or Quaternary felsic intrusive and extrusive rocks consisting of rhyolite to rhyodacite porphyry, and vent, explosion, and lithic breccia. Dikes of andesite to dacite and tuffaceous rocks are associated with the Canoe Bay prospect. The central part of the prospect is characterized by rocks showing argillic, sericitic, and silicic alteration grading outward into weak propylitic alteration. Igneous rocks intrude shale, sandstone, and conglomerate of the Cretaceous Hoodoo Formation. Field observations include a local red color anomaly and cobbles of bleached (altered or deeply weathered), sometimes brecciated, intrusive(?) rocks characterized by subhedral to euhedral quartz crystals, argillic alteration, and numerous small quartz veins. Gold was detected in mineralized rocks that had gold values as high as 0.1 ppm. The highest concentrations (0.1 ppm) were from two rock samples collected during geologic mapping studies. In addition, seven altered quartz diorite(?) samples contained 0.002–0.072 ppm gold and as much as 3 ppm silver. Three quartz vein samples contained as much as 0.012 ppm gold and 1 ppm silver. One stream-sediment sample, collected on the north fork of a small northeast-trending drainage that bisects the hill of the Canoe Bay prospect, had the highest gold concentration (2.8 ppm) obtained from all analyzed stream sediment samples. From the same site, a bulk-concentrate sample was collected that contained 820 μg of gold. One nonmagnetic heavy-mineral-concentrate and four additional bulk-concentrate samples, collected from small streams draining the prospect, contained lesser amounts of gold. Silver concentrations as high as 1 ppm were determined for stream sediments and one value of 50 ppm was determined for the nonmagnetic heavy-mineral concentrate.

Area 6 (plate 1) extends eastward from area 5 to Hoodoo Mountain and the upper Beaver River drainage basin. The area is primarily underlain by clastic rocks of the Hoodoo and Chignik Formations and Tertiary intrusive rocks. Pebble or breccia dikes are found in quartz diorite and sedimentary rocks at the head of Four Bear Creek (Wilson and others, 1988). Red color anomalies, silicified rocks, and local argillic and sericitic alteration are present in area 6. A zone of contact metamorphism located north and west of Four Bear Creek produced several gold anomalies from panned-concentrate and rock samples. An altered andesite(?) sample collected at the head of Four Bear Creek contained 0.05 ppm gold. Twelve panned-concentrate samples, collected from tributaries of Four Bear Creek, upper Canoe Bay River, and from small drainage basins along the north side of the ridge north of Four Bear Creek, produced gold concentrations ranging from 3.3 to 70 μg/pan from bulk concentrates and 20 and 150 ppm from nonmagnetic heavy-mineral concentrates. The two highest gold concentrations were obtained from samples collected on either side of the saddle between the west fork of upper Four Bear Creek and the drainage basin to the north. Gold flakes were also identified in five nonmagnetic heavy-mineral concentrates collected along the southern boundary of area 6.

In the upper Beaver River drainage area, tourmaline-cemented breccia pipes occur in the vicinity of a quartz porphyry granodiorite(?) plug and argillically altered andesites and dacites (Wilson and others, 1988). Red color anomalies and intrusive rocks, similar to those described in area 5, were seen in the upper Beaver River valley and on the east side of Hoodoo Mountain. Tourmaline- and galena-bearing quartz veins were seen in the upper Beaver River valley. Anomalous gold concentrations occur in many panned concentrates and rock samples collected from the upper Beaver River drainage basin including the east side of Hoodoo Mountain. In the upper Beaver River valley and Hoodoo Mountain area, the eight rock samples that had the highest gold concentrations included quartz diorite and andesite with disseminated pyrite, contact-metamorphosed clastic rocks, and a galena-bearing quartz vein sample. Gold concentrations ranged from 0.042 to 0.22 ppm, and the samples contained as much as 20 ppm silver. Along the east side of Hoodoo Mountain, a bulk concentrate had a gold value of 2.3 μg/pan, and a nonmagnetic heavy-mineral concentrate contained two flakes of gold. In the upper Beaver River valley, three nonmagnetic heavy-mineral concentrates contained 30 to 100 ppm gold and 20 to 300 ppm silver. Eight bulk concentrates contained gold ranging from 1.1 to 15 μg/pan.

Area 7 (plate 1) is an area defined by scattered anomalous gold concentrations determined from panned-concentrate samples collected from the middle and lower Beaver River drainage basin. The northern part of area 7 is underlain by fine-grained clastic rocks of the Hoodoo Formation. Quartz-calcite veins are numerous and diorite dikes also occur. The southern part of area 7 is predominantly underlain by clastic rocks of the Tolstoi and Stepovak Formations and by the Meshik Volcanics. Alteration is not obvious except for minor iron-oxide-stained rocks along the ridge to the east of area 7. On the west side of the Beaver River valley, two bulk concentrates collected from east-flowing tributary streams located 2 and 6 km north of Beaver Bay contained gold concentrations of 4.1 and 12 μg/pan. A nonmagnetic heavy-mineral concentrate from the latter site contained more than 1,000 ppm gold and 700 ppm silver. In the east-central part of the Beaver River valley, six bulk-concentrate sites had gold concentrations ranging from 0.7 to 20 μg/pan. The site with the highest bulk-concentrate gold value also contained more than 1,000 ppm gold and 3,000 ppm silver in a nonmagnetic heavy-mineral concentrate. This site is located about 8 km north of Beaver Bay and about 3 km east of the Beaver River. Anomalous gold concentrations, however, were lacking in rock samples collected from area 7. In addition, few anomalous concentrations of other elements were determined from rock, concentrate, or sediment samples collected in area 7. No sulfides were noted in quartz veins from the area, although limonite is a common constituent.

At the mouth of the Beaver River, 300, 1,900, and 6,100 μg of very fine-grained gold occurred in three bulk concentrates collected from black-sand beach deposits. These black sand lenses appear to comprise only a small percentage of the total volume of the beach deposits and probably do not constitute a resource. Large-volume random samples would have to be collected, processed, and analyzed to properly evaluate the economic potential of this gold anomaly. Gold was detected in many samples and in all sample media collected within the Beaver River drainage basin, indicating a probable source area for the beach deposits.

Area 8 (plate 1) is an east-west-trending zone that includes the Pyramid porphyry copper prospect (Christie, 1975; Christie and Wolfhard, 1977). The western half of the area is underlain by the Hoodoo Formation, which contains quartz-calcite veins. Pyramid Mountain is underlain by the Tolstoi Formation, which is intruded by bodies of late Miocene quartz diorite. The Pyramid porphyry copper prospect shows porphyry-type mineralization and alteration in quartz diorite intrusive rocks and Eocene sedimentary rocks. The deposit is zoned outward from a barren potassic core, through a zone of strong pervasive sericitic alteration, to a propylitic margin. Ore reserves of 126 million tons of 0.413 percent copper and 0.025 percent molybdenum have been determined. Seven analyzed intrusive rock and altered sandstone samples collected from Pyramid Mountain contained gold concentrations ranging from 0.02 to 0.30 ppm. About 1 km to the west of the mountain, small drainage basins along the west side of a low divide were sampled: anomalous gold concentrations were found to be 0.4 and 1.0 μg/pan in two bulk concentrates and 30 and 200 ppm in two nonmagnetic heavy-mineral concentrates. The nonmagnetic heavy-mineral concentrates contained 30 and 100 ppm silver, respectively. In the same area, 0.036 ppm gold was determined for a sericitically altered andesite sample.

Area 9 (plate 1) is located between Albatross Anchorage, San Diego Bay, and Dorenoi Bay and includes the San Diego Bay porphyry copper prospect (Wilson and others, 1988). The prospect was drilled in 1975 for porphyry evaluation and was later extensively sampled primarily for gold. The area is a 50 km^2 color anomaly in Miocene volcanic rocks. Small stocks and northwest-trending dikes of diorite and quartz diorite occur but are difficult to distinguish texturally from the intruded andesite. Sericitically altered rocks are common, and the area includes widely scattered zones of intense silicification with strongly developed stockwork veining. Gold concentrations in veins rarely exceed 2 ppm and the highest reported gold concentrations occur in quartz-barite-carbonate veins. Two bulk-concentrate samples with gold concentrations of 1.4 and 8 μg/pan and two nonmagnetic heavy-mineral concentrates with gold concentrations of 300 ppm (70 and 200 ppm silver) occur between San Diego and Dorenoi Bays. Only one stream-sediment sample was analyzed from area 9. This sample was collected from a drainage basin that extends northwest from the head of San Diego Bay. The sample was analyzed twice and averaged 1.7 ppm gold. Several gold values were determined for rocks collected primarily in the western half of area 9. Gold concentrations of 0.02 and 0.10 ppm were determined for quartz-vein samples; pyrite-bearing andesite samples contained 0.01 and 0.014 ppm, and a fine-grained felsic intrusive rock sample contained 0.004 ppm gold.

Area 10 (plate 1) is a north-south-trending zone extending south from Mud Bay to the southern end of Grass Valley. An altered zone covers an area of Tertiary intrusive rocks and surrounding Tertiary volcanic rocks. The Stepovak and Tolstoi Formations also underlie a part of area 10. Field observations include scattered red color anomalies. Two mineral occurrences are described within area 10 (Wilson and others, 1988). A mineralized coarse-grained granodiorite pluton with many pyrite-bearing quartz veins is located at the upper end of the valley northeast of Grass Valley, and a concentrate sample collected from the drainage basin to the north contained 20 ppm silver. The Mud Bay occurrence, located on a ridge 7 km south-southwest of Mud Bay, consists of siltstone and sandstone of the Stepovak Formation cut by andesite(?) dikes and by veins containing masses of galena (Wilson and others, 1988). A sulfide vein sample collected at the Mud Bay occurrence contained 0.3 ppm gold, 5,000 ppm silver, more than 2 percent lead, more than 2 percent zinc, and more than 1 percent antimony. Four panned concentrates collected from drainage basins to the northeast, east, and southeast contained gold concentrations of 0.5 to 2.8 μg/pan for bulk concentrates and 100 ppm gold and as much as 20 ppm silver from nonmagnetic heavy-mineral concentrates. A nonmagnetic heavy-mineral-concentrate sample and a bulk-concentrate sample, collected from the main south-flowing drainage just south of Mud Bay and from an east-flowing tributary drainage located 3 km south of Mud Bay, had gold concentrations of 100 ppm and 0.5 μg/pan, respectively.

Area 11 (plate 1) is located northeast of Grub Gulch and is centered around an altered Tertiary quartz diorite pluton. Rocks in the vicinity have undergone phyllic, argillic, and propylitic alteration and are cut by quartz and pyrite veins (Wilson and others, 1988). Most of the area is underlain by Tertiary volcanic rocks and, to a lesser extent, by the Tolstoi Formation. Gold occurs in a stream-sediment sample (0.02 ppm), in a nonmagnetic heavy-mineral concentrate (100 ppm gold, 50 ppm silver), and in two bulk concentrates (31 and 70 μg/pan). Gold concentrations in four altered andesite samples range from 0.006 to 0.042 ppm.

Area 12 (plate 1) is a southwest- to northeast-trending zone that includes the Ivanof porphyry copper prospect (MacKevett and Holloway, 1977). The prospect consists of a small quartz diorite pluton that intrudes both sandstone and conglomerate of the Tolstoi Formation. Veinlet and replacement mineralization occurs in the intrusive rocks as well as in the country rocks. Rocks in the area have been subjected to minor potassic and sericitic alteration and widespread propylitic alteration and silicification. Grades as high as 0.72 percent copper are reported; there is a potential for large tonnages (Green and others, 1988). Red color anomalies occur in the area and molybdenite flakes are relatively abundant in nonmagnetic heavy-mineral concentrates collected around the prospect. Northeast of the Ivanof porphyry copper prospect, area 12 is underlain by clastic rocks of the Naknek Formation and by Tertiary volcanic rocks. Several anomalous gold concentrations were determined from panned-concentrate and rock samples collected around the Ivanof porphyry copper prospect. Five bulk concentrates had gold concentrations ranging from 0.3 to 89 μg/pan associated with silver concentrations as high as 50 ppm. One nonmagnetic heavy-mineral concentrate contained 20 ppm gold and 5 ppm silver. Five samples of quartz diorite and granodiorite had gold concentrations ranging from 0.04 to 0.1 ppm; one diorite sample contained 0.8 ppm, and a vein sample contained 0.1 ppm. Samples collected from streams draining the small hills northeast of the Ivanof porphyry copper prospect yielded two gold values: 14 μg/pan from a bulk concentrate and 0.006 ppm from a cobble of pyrite-rich andesite. About 11 km northeast of the Ivanof porphyry copper prospect, samples collected from a drainage basin on the west side of the Kametolook River contained a gold concentration of 7.3 µg/pan in a bulk concentrate, and a flake of gold was identified in the nonmagnetic heavy-mineral concentrate.

Area 13 (plate 1) lies in the central part of the Kupreanof Peninsula and is underlain by the Meshik Volcanics and by other Tertiary volcanic and intrusive rocks. Gold was visually identified in one nonmagnetic heavy-mineral concentrate and gold concentrations of 8.1 and 70 µg/pan were determined for two bulk concentrates. Gold was not determined in rock samples. Minor red color anomalies were seen in the area.

Area 14 (plate 1) is located on Mitrofania Island and is underlain by Tertiary volcanic rocks in contact with rocks of the Miocene Devils batholith. A bulk concentrate containing 1.7 µg of gold was collected from the northeastern part of the island, but no gold was detected in three samples of altered andesite collected in this area. Gold concentrations as high as 3.0 ppm were determined from quartz-calcite-sulfide vein samples collected along the west coast of Mitrofania Island. These vein samples also contained as much as 50 ppm silver, 26,000 ppm arsenic, 2,000 ppm antimony, and 190 ppm bismuth.

Area 15 (plate 1) extends northward from Herring Lagoon into the Chignik quadrangle between Fishrack and Kuiukta Bays. The area is underlain by the Tolstoi and Hoodoo Formations plus Tertiary volcanic rocks in contact with the Devils batholith. A vein sample contained 3.4 ppm gold and a value of 80 µg/pan was obtained from a bulk-concentrate sample.

Area 16 (plate 1) lies in an area of red color anomalies in the northwestern part of Dolgoi Island. A propylitically and argillically altered Miocene quartz diorite body intrudes tuffaceous rocks of the Belkofski Formation (Angeloni and others, 1985). Gold occurs in one bulk-concentrate sample (2.5 µg/pan), one nonmagnetic heavy-mineral concentrate (100 ppm gold, 3,000 ppm silver), and in two stream-sediment samples (0.004 ppm). Gold concentrations of 0.002 and 0.004 ppm were determined in altered andesite and 0.015 ppm gold was determined in a shale sample.

Area 17 (plate 1) lies on Nagai Island and extends from East Bight north to inner Porpoise Harbor and northwest to inner Sanborn Harbor. The area is underlain by clastic rocks of the Shumagin Formation that are intruded by dacite dikes. A rock sample from one of these dikes was determined to be the same age as the Shumagin Islands batholith, which is exposed south of area 16. Disseminated sulfides in sandstone, numerous quartz veins, and contact-metamorphosed rocks occur in the area. Gold was determined in two bulk-concentrate samples (0.3 and 1.5 µg/pan) and in two nonmagnetic heavy-mineral concentrate samples (200 and 500 ppm gold, 70 and 5 ppm silver) that were collected at four sites surrounding area 17. Gold also was determined in a stream-sediment sample (0.002 ppm) and in four rock samples collected within area 17. Three samples of felsic dike material contained 0.012, 0.05, and 0.16 ppm gold and a sample of sandstone with disseminated sulfides contained 0.014 ppm gold and 5 ppm silver.

Area 18 (plate 1) consists of two drainage basins on Big Koniuji Island. Gold was detected there in one stream-sediment sample (less than 0.002 ppm) and gold flakes were identified in two nonmagnetic heavy-mineral concentrates. Four samples of shale and siltstone collected near the Shumagin Islands batholith contained 0.002–0.022 ppm gold. Quartz-vein material was noted at one site but was not collected for analysis.

Area 19 (plate 1) includes the northeastern part of Little Koniuji Island north of Sandy Cove. The area is underlain by the Shumagin Islands batholith and gold concentrations of 0.002 ppm and 0.15 ppm were determined in granodiorite samples.

Only 16 of the 173 rock samples analyzed for gold that had values equal to or greater than 0.004 ppm were collected from areas other than the 19 areas discussed above, and only one of these 16 samples was associated with a panned-concentrate gold value. Of the 16 rock samples, an altered andesite with disseminated pyrite (0.004 ppm gold) and an altered intrusive rock (0.04 ppm gold) were collected from the south end of Inner Iliasik Island and the north end of Outer Iliasik Island, respectively, in the southwestern corner of the study area. To the northwest, north of Volcano Bay, an iron-oxide-stained and bleached cobble collected from stream gravel derived from the Belkofski Formation contained disseminated pyrite and 0.004 ppm gold. Kennedy and Waldron (1955) report that prospectors had seen gold while panning near the head of Volcano Bay. Iron-oxide-stained andesite float (0.004 ppm gold) was collected from a small stream that drains the Stepovak Formation and Meshik Volcanics and flows into the west side of Beaver Bay. The sample is associated with two bulk-concentrate gold anomalies. The source of the gold, however, may be the Beaver River drainage basin because gravel deposits appear to extend down the west side of Beaver Bay from the Beaver River.

Six samples of andesite, silicified andesite, and sandstone, with varying amounts of disseminated and vein pyrite (0.006–0.12 ppm gold), were collected from drainage basins surrounding the high, largely ice-covered spine of the Aleutian Range, which extends northeast from the American Bay-Right Head area. The area is underlain by Tertiary and Quaternary volcanic rocks and is characterized by large areas of heavily iron-oxide-stained, pyrite- and silica-rich rock. Fumarole-type sulfur occurrences also have been found in this area. On the north end of the Kupreanof Peninsula, along the east-west-trending valley north of Osterback Creek, a sample of rhyodacite with disseminated pyrite (0.02 ppm gold) was collected from the Meshik Volcanics. To the east, in the southeastern part of Paul

Island, an iron-oxide-stained volcanic rock sample (0.026 ppm gold) was also collected from the Meshik Volcanics. Slightly north of the northeastern corner of the study area, a sample of altered granodiorite (0.03 ppm gold) from the Devils batholith was collected along Seal Bay. Along the north shore of Popof Island and at Cape Devine on Korovin Island, samples of shale collected from Popof volcanic rocks contained 0.01 and 0.08 ppm gold, respectively. South of Cape Devine, a sample of andesite with disseminated pyrite (0.004 ppm gold) was collected from an area underlain by the Popof volcanic rocks on Andronica Island.

Several panned-concentrate and stream-sediment gold anomalies also occur outside of the 19 numbered areas. Gold flakes were noted in two nonmagnetic heavy-mineral concentrates collected along the west side of a ridge extending north-northwest from Mount Dana, perhaps indicating that area 5 extends north of Mount Dana. However, no other element was found in this area in anomalous concentrations. Arcuate glacial moraine deposits occur north of Mount Dana; this suggests that gold may have been transported northward by glacial action. A flake of gold seen in a nonmagnetic heavy-mineral concentrate collected 20 km northeast of Mount Dana was probably transported by glacial processes. Pyroclastic and debris-flow deposits of Holocene age that surround Mount Dana are a possible source for gold, although most panned concentrates collected from the area of these deposits do not contain detectable gold. A sample site west of Jackson Lagoon on the northwest shore of Pavlof Bay is also located in an area of glacial deposition. The nonmagnetic heavy-mineral concentrate collected at this site contained 1,000 ppm gold and 500 ppm silver. Pyrite is present in this concentrate sample and also in a cobble of andesite collected from the same site. The andesite sample contains anomalous concentrations of silver, mercury, and arsenic. The geochemical anomalies obtained from samples collected at this site may indicate the presence of mineralized rock presently covered by Holocene deposits. However, no gold was detected in two stream-sediment samples collected at this site, and the nonmagnetic heavy-mineral concentrates and stream sediments did not contain anomalous concentrations of other elements. A single-element gold determination (detected, but less than 20 ppm) from the mouth of Wolverine Gulch, located southeast of Canoe Bay, may have been derived from sediments transported down the Canoe Bay River valley during the time of glaciation. Further to the southwest, gold (43 μg/pan) occurs in a bulk concentrate collected from a small stream draining the northeast side of Bobrovia Mountain, an area underlain by Tertiary volcanic rocks and the Unga Formation. No other elements were found in this area in anomalous concentrations. About 7 km southeast of the mouth of the Beaver River, a flake of gold was seen in a nonmagnetic heavy-mineral concentrate collected downstream from a small red color anomaly in an area underlain by the Unga Formation and Tertiary volcanic rocks. Other elements were not found in anomalous concentrations. Cobbles of quartz-vein material were noted at the site but were not collected for analysis. Cobbles of an aphanitic volcanic rock with quartz phenocrysts and disseminated pyrite were collected from the adjacent drainage basin to the northeast, but no anomalous concentrations of gold or other elements were detected in these cobbles.

Additional panned-concentrate and stream-sediment gold values occurring outside of the 19 numbered areas were determined at the sites described below. The headland separating Lefthand Bay and Albatross Anchorage is underlain by Tertiary volcanic rocks and by the Stepovak Formation. Gold concentrations occur in this area in two bulk concentrates (0.5 and 2.1 μg/pan) but not in analyzed rock samples. Samples from this area contain anomalous concentrations of other elements, however, and quartz and calcite-pyrite veins occur in pyrite-bearing andesite. A flake of gold was seen in a nonmagnetic heavy-mineral concentrate collected 1 km southeast of Marble Point on Herendeen Bay. Samples collected from this site did not contain anomalous concentrations of other elements. Calcarenite of the Herendeen Formation underlies this area and two intersecting faults are mapped at the site. Iron-oxide-stained rock cobbles were noted at the site but were not collected for analysis. Along the upper eastern section of Coal Valley, located northwest of area 10, a gold value of 110 μg/pan occurred in a bulk concentrate. A flake of gold was also seen in a nonmagnetic heavy-mineral concentrate collected 2 km downstream. This area is underlain by clastic rocks of the Naknek, Staniukovich, Herendeen, and Chignik Formations. Iron-oxide-stained rocks occur in the upper valley. Only one panned-concentrate gold value (detected, but less than 20 ppm) occurred in the drainage basins surrounding the spine of the Aleutian Range northeast of Right Head and American Bay. The sample was collected from the northeast side of the drainage basin that extends southeast from Bear Lake. Samples collected at this site did not contain anomalous concentrations of other elements. A bulk-concentrate sample (collected from a large drainage basin northwest of area 12) contained 1.5 μg of gold and is associated with other anomalous element concentrations. The area is underlain by the Naknek, Chignik, and Tolstoi Formations and the Meshik Volcanics. Another bulk-concentrate sample that contained 6 μg of gold was collected from a small drainage basin underlain by the Tolstoi Formation. This sample site is located between Ivan Bay and Fishrack Bay in the northeastern corner of the study area. Cobbles of quartz-vein material were noted but were not collected for analysis. A stream-sediment sample collected from the northwestern part of Korovin Island had a gold value of 0.4 ppm, although no other elements were found in anomalous concentrations. In addition to the panned-concentrate gold values that surround area 17, two nonmagnetic heavy-mineral-concentrate gold values of 20 and 200 ppm (7 and 20 ppm silver) occur to the southeast on Nagai Island. Most of the gold anomalies determined on Nagai Island and on Big and Little Koniuchi

Islands were obtained from samples collected from the Shumagin Islands batholith, from dikes determined to be the same age as the batholith, or from the Shumagin Formation close to these intrusive rocks.

CENTERS OF PORPHYRY COPPER-MOLYBDENUM-TYPE MINERALIZATION

A center of porphyry-type mineralization is defined here as a drainage basin or group of contiguous drainage basins that are characterized by both copper and molybdenum anomalies in the stream-sediment or nonmagnetic heavy-mineral-concentrate samples—these basins are generally surrounded by drainage basins anomalous in selected elements associated with porphyry systems. Drainage basins representing centers of mineralization are delineated by solid lines on plate 2 and on figures 7–16. Rock samples with anomalous copper and molybdenum values are also plotted for reference because they may be associated with porphyry copper-molybdenum systems. As on plate 1, the dashed lines delineate conspicuous areas of multielement, base- and precious-metal anomalies in stream-sediment samples and nonmagnetic heavy-mineral-concentrates (Frisken and Arbogast, 1991a, 1991b). Much of the known copper-molybdenum mineralization is characterized by hydrothermally altered rocks that are rich in finely disseminated pyrite and associated red color anomalies. Exposures of plutonic or hypabyssal intrusive rocks of intermediate composition are usually present. Zoned alteration patterns are seen around the areas of mineralization in rocks that show potassic, sericitic, and (or) argillic alteration near the center of the systems and in rocks that show propylitic alteration away from the centers.

The most conspicuous areas of porphyry mineralization include drainage basins containing both stream-sediment and nonmagnetic heavy-mineral-concentrate copper-plus-molybdenum anomalies. Ten centers of mineralization are delineated in the study area that have copper-plus-molybdenum anomalies in both stream-sediment and nonmagnetic heavy-mineral concentrates. These 10 centers, which include all of the previously known porphyry copper and molybdenum prospects, are numbered on plate 2 and are discussed below. Anomalous concentrations of gold were determined in stream-sediment, concentrate, and (or) rock samples collected from all 10 centers. Some or all of the centers may fit porphyry copper-gold mineral deposit model 20C described by Cox and Singer (1986). This model is characterized by having a gold (ppm) to molybdenum (percent) ratio greater than 30 in the ore zones. Several rock samples from the study area, including rock samples collected in areas 2, 3, 5, 7, and 10, have ratios greater than 30, but it is not known if any of these samples were collected from the centers of porphyry systems. More detailed outcrop or drill core sampling is required to determine mineral-deposit types. Figures 7–16 show the 10 centers of mineralization and sample locations in the vicinity of each center. Tables 8–17 present anomalous concentrations of selected elements determined in the stream sediments and bulk and nonmagnetic heavy-mineral concentrates plotted on figures 7–16. The tables also list ore-related minerals identified in the nonmagnetic heavy-mineral concentrates. The outlined drainage basins shown on figures 7–16 are those represented by copper-plus-molybdenum anomalies in both stream-sediment and nonmagnetic heavy-mineral-concentrate samples. Geological and mineral-exploration data in the following descriptions are from Wilson and others (1988) and the AMRAP geological map (Wilson and others, in press). Some field observations are also included. Because many of the gold occurrences in the study area are probably related to porphyry-type mineralization events, several of the following areas overlap areas previously discussed in the description of gold anomalies section.

Area 1 (plate 2) is centered around the Canoe Bay gold prospect (fig. 7, table 8). Drainage basins within about 5 km of this prospect have anomalous concentrations of copper, molybdenum, silver, gold, lead, zinc, boron, and tin in stream-sediment samples; copper, molybdenum, silver, lead, zinc, arsenic, bismuth, gold, strontium, cadmium, iron, and barium in nonmagnetic heavy-mineral concentrates; and gold in bulk concentrates. Barite-celestite, cinnabar, galena, gold, molybdenite, pyrite, and sphalerite were identified in the nonmagnetic heavy-mineral concentrates. Although this prospect was examined by the Freeport Exploration Company primarily for its gold potential, it is geologically and geochemically typical of all 10 centers of porphyry copper-molybdenum-type mineralization. All mineralized areas have a similar suite of anomalous elements and minerals and similar exposures of hypabyssal or plutonic igneous rocks, often of quartz dioritic composition, which are intruded into clastic and volcanic rocks. Zoned hydrothermal alteration patterns are always present. The most obvious features due to alteration processes are red color anomalies; these areas of oxidized, disseminated pyrite are quite extensive in certain parts of the study area.

Area 2 (plate 2) is located in the upper end of the Beaver River drainage basin (fig. 8, table 9). Drainage basins within about 5 km of this mineralization center have anomalous concentrations of copper, molybdenum, silver, lead, zinc, boron, and arsenic in stream-sediment samples; copper, molybdenum, silver, lead, zinc, boron, tin, arsenic, antimony, bismuth, gold, strontium, cadmium, iron, and barium in nonmagnetic heavy-mineral concentrates; and gold in bulk concentrates. Barite-celestite, cinnabar, galena, gold, molybdenite, pyrite, scheelite-powellite, and sphalerite were identified in the nonmagnetic heavy-mineral concentrates. The geologic map (plate 3) shows area 2 to be underlain primarily by clastic rocks of the Upper Cretaceous Hoodoo and Chignik Formations. In the upper Beaver River valley, the Hoodoo and Chignik Formations are overlain by sedimentary rocks of the Paleocene and Eocene Tolstoi Formation and by Quaternary volcanic rocks. An altered zone is shown around a Tertiary intrusion, and altered rocks are also mapped around Hoodoo Mountain.

Area 3 (plate 2) is located in the Pyramid Mountain area and includes the Pyramid porphyry copper prospect (fig. 9, table 10). Drainage basins within about 5 km of this mineralization center have anomalous concentrations of copper, molybdenum, silver, lead, zinc, and boron in stream-sediment samples and copper, molybdenum, silver, lead, zinc, boron, arsenic, antimony, bismuth, gold, strontium, cadmium, iron, tungsten, and barium in nonmagnetic heavy-mineral concentrates. Barite-celestite, galena, molybdenite, pyrite, scheelite-powellite, and sphalerite were identified in nonmagnetic heavy-mineral concentrates. Area 3 is underlain by clastic rocks of the Hoodoo and Tolstoi Formations, which are intruded by quartz diorite. Clastic rocks of the upper Eocene and lower Oligocene Stepovak Formation and upper Miocene volcanic rocks also occur in area 3. A second intrusive body and associated area of altered rock is located 4 km northeast of the Pyramid porphyry copper prospect. This area was not directly sampled during the geochemical reconnaissance study, although a panned-concentrate sample was collected in the valley on the east side of the area along a large stream.

Area 4 (plate 2) is located between Albatross Anchorage, San Diego Bay, and Dorenoi Bay and includes the San Diego Bay gold and porphyry copper prospect (fig. 10, table 11). Drainage basins within about 5 km of this mineralization center have anomalous concentrations of copper, molybdenum, silver, gold, lead, zinc, boron, and tin in stream-sediment samples; copper, molybdenum, silver, lead, zinc, tin, bismuth, gold, strontium, cadmium, iron, and barium in nonmagnetic heavy-mineral concentrates; and gold in bulk concentrates. Barite-celestite, fluorite, galena, molybdenite, pyrite, and sphalerite were identified in nonmagnetic heavy-mineral concentrates.

Area 5 (plate 2) is located near the eastern upper end of Grass Valley (fig. 11, table 12). Drainage basins within about 5 km of this mineralization center have anomalous concentrations of copper, molybdenum, silver, lead, zinc, and boron in stream-sediment samples; copper, molybdenum, silver, lead, zinc, boron, arsenic, antimony, bismuth, gold, strontium, cadmium, iron, tungsten, and barium in nonmagnetic heavy-mineral concentrates; and gold in bulk concentrates. Barite-celestite, pyrite, and scheelite-powellite were identified in nonmagnetic heavy-mineral concentrates. The geologic map (plate 3) shows an altered zone covering both an area of Tertiary intrusive rocks and surrounding Tertiary volcanic rocks. A mineral occurrence located at the upper end of the valley northeast of Grass Valley is described as a mineralized coarse-grained granodiorite pluton with many quartz-pyrite veins. Scattered red color anomalies were seen in the area.

Area 6 (plate 2) is located in the Grub Gulch (Dent Point) area (fig. 12, table 13). Drainage basins within about 5 km at this mineralization center have anomalous concentrations of copper, molybdenum, silver, gold, lead, and zinc in stream-sediment samples; copper, molybdenum, silver, lead, zinc, boron, tin, arsenic, antimony, bismuth, gold, strontium, cadmium, iron, tungsten, and barium in nonmagnetic heavy-mineral concentrates; and gold in bulk concentrates. Barite-celestite, galena, pyrite, and sphalerite were identified in nonmagnetic heavy-mineral concentrates.

Area 7 (plate 2) includes the Ivanof porphyry copper prospect (fig. 13, table 14). Drainage basins within about 5 km of this mineralization center have anomalous concentrations of copper, molybdenum, silver, and detectable gold in stream-sediment samples; copper, molybdenum, silver, lead, zinc, boron, tin, arsenic, bismuth, gold, and iron in nonmagnetic heavy-mineral concentrates; and gold in bulk concentrates. Chalcopyrite, galena, molybdenite, and pyrite were identified in nonmagnetic heavy-mineral concentrates.

Area 8 (plate 2) is located in the northwestern part of Dolgoi Island (fig. 14, table 15). Drainage basins within about 5 km of this mineralization center have anomalous concentrations of copper, molybdenum, silver, gold, lead, and zinc in stream-sediment samples; copper, molybdenum, silver, lead, zinc, boron, tin, bismuth, gold, cadmium, iron, and barium in nonmagnetic heavy-mineral concentrates; and gold in bulk concentrates. Barite-celestite, pyrite, cinnabar, and sphalerite were identified in nonmagnetic heavy-mineral concentrates.

Area 9 (plate 2) is located in the center of Unga Island south of Zachary Bay (fig. 15, table 16). Drainage basins within about 5 km of this mineralization center have anomalous concentrations of copper, molybdenum, silver, gold, lead, and zinc in stream-sediment samples; copper, molybdenum, silver, lead, zinc, tin, arsenic, strontium, cadmium, iron, and barium in nonmagnetic heavy-mineral concentrates; and gold in bulk concentrates. Barite-celestite, gold, molybdenite, and pyrite were identified in nonmagnetic heavy-mineral concentrates. The geologic map (plate 3) shows Tertiary intrusive bodies and areas of alteration in the upper Eocene and lower Oligocene Popof volcanic rocks and, to a lesser degree, in rocks of the upper Oligocene to middle Miocene Unga Formation near Zachary Bay. Red color anomalies and propylitically altered, quartz-rich intrusive(?) rocks were noted in the area. Area 9 contains a base-metal prospect and a base-metal mineral occurrence and has precious-metal prospects and occurrences to the north, east, and south. The Zachary Bay base-metal prospect is described as mineralization associated with a feldspar porphyry body on the western edge of a color anomaly. Quartz diorite intrudes andesite; propylitic, sericitic, magnetite-plagioclase, and rare potassic (biotite) alteration is reported. Drilling in 1975 produced assay values from a 46 m interval as high as 0.36 percent copper, 0.004 percent molybdenum, 0.08 oz/ton silver, and 0.016 oz/ton gold. The Zachary Bay

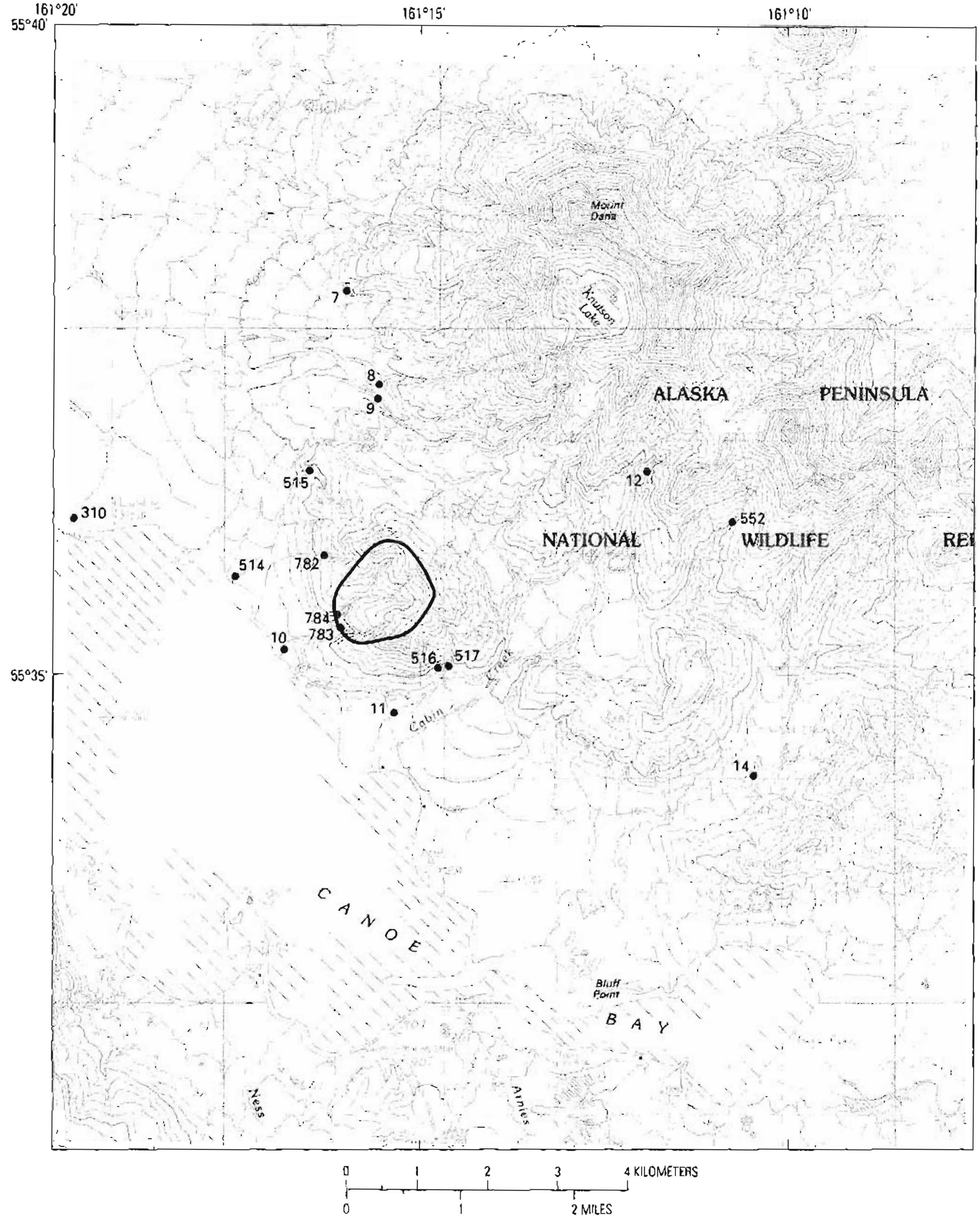


Figure 7. Sample site map for area 1 (plate 2). Drainage basin containing centers of mineralization delineated by solid line. Sample sites shown by solid circle and site number.

Table 8. Summary of selected geochemical anomalies for samples plotted on figure 7 (area 1 on plate 2)

[All values in ppm except for Fe (in percent) and bulk-concentrate Au (in micrograms of gold per pan). The following abbreviations are used: L, detected but less than; G, greater than; Py, pyrite; Gal, galena; Mol, molybdenite; Cin, cinnabar; Bar-Cel, barite-celestite; and Sph, sphalerite. Leaders (--), no anomalous data]

Sample site	Anomalous values from sediments	Anomalous values from concentrates	Minerals identified in concentrates
7	50 Pb	20 Ag; 5000 Pb; 1500 As;	Py, Gal, Mol.
8	--	15 Ag; 3000 Pb	Cin, Py, Bar-Cel
9	70 B	300 Pb; 500 As	Py, Bar-Cel Cin
10	200 Cu; 20 Sn	20 Ag; 300 Cu; 5000 Zn; 100 Au; 200 Cd; L(20) Bi	Py, Gold
11	--	--	
12	--	--	
14	--	--	
310	1 Ag	--	
514	300 Zn	22 μg pan Au	
515	300 Zn	2000 Sr	
516	L(0.5) Ag	1000 Pb; 2000 Sr; G(10,000) Ba	
517	--	5 Ag; 2000 Pb; 0.5 μg/pan Au	
552	--	20 Bi	
782	1 Ag; 200 Pb; 200 Zn	50 Ag; 3000 Pb; 2000 Zn; 2000 As; 32 μg/pan Au	Py
783	0.7 Ag; 300 Zn; 7 Mo	200 Cu; 50 Mo; 5 Ag; 300 Pb; 10,000 Zn; 20 Fe; 18 μg/pan Au	Py, Sph
784	1 Ag; 50 Pb; 300 Zn; 5 Mo; 100 Cu; 2.8 Au	300 Cu; 20 Ag; 300 Pb; 10,000 Zn; 50 Cd; 30 Fe; G(10,000) Ba; 820 μg/pan Au	Py, Gold

breccia occurrence is described as a 15-m-wide exposure of brecciated, silicified, pyrite-rich andesite with analytical values as high as 1.09 oz/ton silver, 2.07 percent zinc, and 0.58 percent lead.

Area 10 (plate 2) is located in the east-central part of Popof Island (fig. 16, table 17). Drainage basins within about 5 km of this mineralization center have anomalous concentrations of copper, molybdenum, gold, zinc, and boron in stream-sediment samples and copper, molybdenum, silver, lead, zinc, tin, arsenic, gold, strontium, cadmium, iron, tungsten, and barium in nonmagnetic heavy-mineral concentrates. Barite-celestite, cinnabar, fluorite, pyrite, molybdenite, and sphalerite were identified in nonmagnetic heavy-mineral concentrates. The geologic map (plate 3) shows alteration in the Popof volcanic rocks. Field observations include red color anomalies, intrusive(?) rocks, and abundant sphalerite in one panned concentrate.

In addition to the 10 centers of mineralization discussed above, other copper-plus-molybdenum anomalies were found in: stream-sediment samples (11 sites), nonmagnetic heavy-mineral-concentrate samples (9 sites), in a combination of stream-sediment and nonmagnetic heavy-mineral-concentrate samples (5 sites), and in rock samples (9 sites). Many of these sites are located near one of the 10 numbered areas on plate 2 or are spatially associated with one of the 19 areas of anomalous gold values mentioned previously. These additional anomalous sample sites are discussed below.

A site at Moss Cape in the southwestern corner of the study area contained 50 ppm copper and 5 ppm molybdenum in the stream-sediment sample and 200 ppm copper associated with lead, zinc (10,000 ppm), cadmium, iron, and pyrite anomalies in the nonmagnetic heavy-mineral concentrate. The area is underlain by Tertiary intrusive and volcanic rocks. Field observations include iron-oxide-stained rocks and quartz-pyrite-rich altered rocks.

A sample of andesite with disseminated pyrite collected from the Four Bear Creek drainage basin contained 200 ppm copper, 100 ppm molybdenum, and 0.004 ppm gold. This area of copper, molybdenum, silver, gold, lead, boron, and barium anomalies includes a mineral occurrence described as pebble or breccia dikes occurring in quartz diorite and nearby sedimentary rocks (Wilson and others, 1988).

Three sites define a geochemically anomalous area in the east-central part of the Beaver River drainage basin. This area contains 70 ppm copper in a stream-sediment sample

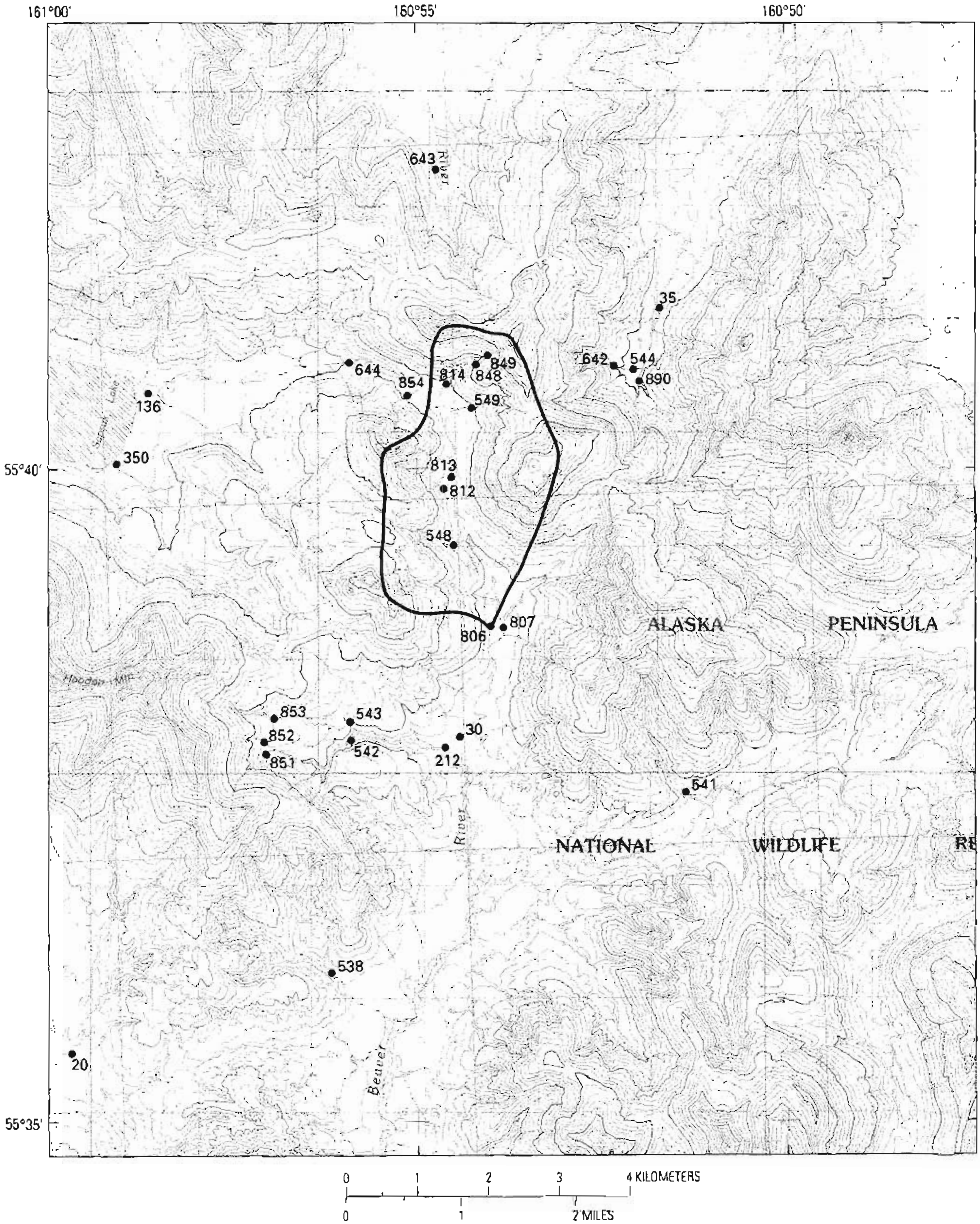


Figure 8. Sample site map for area 2 (plate 2). Drainage basin containing centers of mineralization delineated by solid line. Sample sites shown by solid circle and site number.

Table 9. Summary of selected geochemical anomalies for samples plotted on figure 8 (area 2 on plate 2)

[All values in ppm except for Fe (in percent) and bulk-concentrate Au (in micrograms of gold per pan). The following abbreviations are used: L, detected but less than; G, greater than; Py, pyrite; Bar-Cel, barite-celestite; Gal, galena; Sph, sphalerite; Cin, cinnabar; Mol, molybdenite; and Sch-Pow, scheelite-powellite. Leaders (--), no anomalous data]

Sample site	Anomalous values from sediments	Anomalous values from concentrates	Minerals identified in concentrates
20	--	--	Bar-Cel, Gold
30	100 B	G(10,000) Ba	Py, Bar-Cel, Cin
35	--	G(10,000) Ba	Bar-Cel
136	L(0.5) Ag; 100 B; 200 Pb	2000 B	
212	100 B; 70 Cu	G(10,000) Ba	Py, Bar-Cel, Gold, Sch-Pow
350	--	2000 B	
538	70 B	G(10,000) Ba	
541	70 B	G(10,000) Ba; 10,000 Sr	Bar-Cel
542	70 B	G(10,000) Ba; 7000 Sr	Bar-Cel, Sch-Pow
543	200 Zn	500 As; G(10,000) Ba; 50 Bi; 2000 Sr	Py, Bar-Cel
544	70 B	20 Ag; 1000 As; 5000 B; G(10,000) Ba; 5000 Pb	
548	0.05 Ag	30 Ag; 500 As; G(10,000) Ba; 10 Mo; 2000 Pb;10,000 Sr; 1500 Zn; 15 μg/pan Au	Py, Bar-Cel
549	1 Ag; 200 As; 200 B; 100 Cu; 10 Mo; 100 Pb	20 Fe; 20 Ag; 50 Au; G(10,000) Ba; 200 Cd; 150 Cu; 100 Mo; 300 Pb; 10,000 Zn; 2.7 μg/pan Au	Py, Bar-Cel, Mol
642	100 B; 200 Zn	150 Ag; 1500 As; G(5000) B; G(10,000) Ba; 50 Cd; G(50,000) Pb; 5000 Sr	Py, Bar-Cel
643	100 B	G(5000) B; G(10,000) Ba; 150 Pb	Py, Bar-Cel, Sch-Pow
644	0.5 Ag; 100 B; 150 Pb; 500 Zn	300 Ag; 2000 As; 100 Au; G(5000) B; G(10,000) Ba; 100 Sn; G(50,000) Pb; 7000 Sr; 2000 Zn	Py, Bar-Cel
806	0.7 Ag; 70 B; 5 Mo; 70 Pb	20 Fe; 100 Ag; 10,000 As; 30 Au; 3000 B; G(10,000) Ba; 70 Bi; 100 Cd; 150 Cu; 1500 Pb; 3000 Sr; 10,000 Zn; 1.1 μg/pan Au	Py, Bar-Cel, Gal, Sph
807	L(0.5) Ag	G(10,000) Ba; 2000 Sr	
812	1 Ag; 200 As; 150 Pb; 500 Zn	30 Fe; 200 Ag; G(10,000) As; G(10,000) Ba; 30 Bi; L(50) Cd; 150 Cu; G(50,000) Pb; 200 Sb; 3000 Sr; 1000 Zn; 7.6 μg/pan Au	Py, Bar-Cel
813	(no sample)	(no spectrographic data) 2.9 μg/pan Au	
814	1 Ag; 200 B; 150 Pb	50 Fe; 15 Ag; 1500 As; G(10,000) Ba; 50 Cd; 200 Cu; 700 Pb; 3000 Sr; 5000 Zn; 11 μg/pan Au	Py, Bar-Cel
848	200 Ag; 300 As; 300 B; 100 Cu; 5 Mo; 200 Pb; 700 Zn	300 Ag; 5000 As; G(10,000) Ba; 500 Cd; 200 Cu; 30 Mo; 20,000 Pb; 500 Sb; 2000 Sr; G(20,000) Zn	Py, Bar-Cel, Gal, Sph
849	1 Ag; 500 B; 70 Cu; 5 Mo; 100 Pb; 200 Zn	100 Ag; 1000 As; G(10,000) Ba; 20 Bi; 200 Cd; 300 Cu; 30 Mo; 10,000 Pb; 1000 Sb; 5000 Sr; G(20,000) Zn	Py, Bar-Cel, Gal, Sph
851	100 B	(no spectrographic data)	Py, Bar-Cel
852	100 B	G(10,000) Ba	Py, Bar-Cel
853	100 B; 5 Mo	20 Fe; G(10,000) Ba; 150 Pb; 10 Mo	Py, Bar-Cel
854	L(0.5) Ag; 200 B; 5 Mo; 50 Pb; 500 Zn	30 Fe; 1000 As; G(10,000) Ba; 500 Bi; 1000 Pb; 2000 Sr	Py, Bar-Cel
890	150 B; 100 Cu; 200 Zn	G(10,000) Ba; 200 Pb; 10,000 Sr	Py, Bar-Cel, Sch-Pow

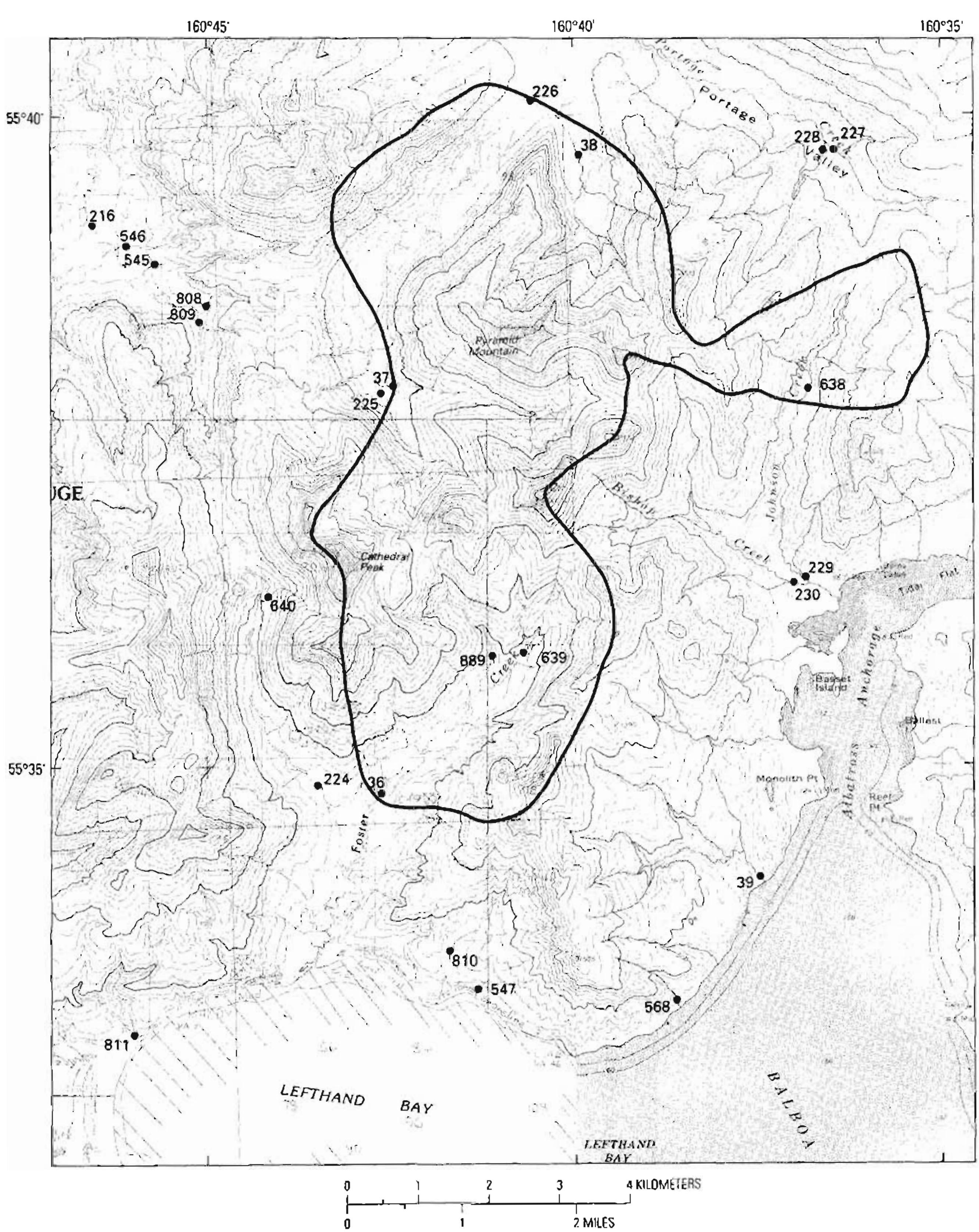


Figure 9. Sample site map for area 3 (plate 2). Drainage basin containing centers of mineralization delineated by solid line. Sample sites shown by solid circle and site number.

Table 10. Summary of selected geochemical anomalies for samples plotted on figure 9 (area 3 on plate 2)

[All values in ppm except for Fe (in percent) and bulk-concentrate Au (in micrograms of gold per pan). The following abbreviations are used: L, detected but less than; G, greater than; Py, pyrite; Bar-Cel, barite-celestite; Gal, galena; Sph, sphalerite; Mol, molybdenite; and Sch-Pow, scheelite-powellite. Leaders (--), no anomalous data]

Sample site	Anomalous values from sediments	Anomalous values from concentrates	Minerals identified in concentrates
36	70 Cu	L(500) As; 50 Cd; 10 Mo; 200 Pb; 1000 Zn	Bar-Cel, Mol
37	L(0.5) Ag; 200 Cu; 200 Mo	200 Cu; 200 Mo; L(100) W;	Py, Mol
38	70 B; 100 Cu; 300 Zn	G(10,000) Ba; 200 Pb; 1000 Zn	Py, Bar-Cel
39	--	L(50) Cd; 1000 Zn	
216	100 B; 70 Cu; 50 Pb	100 Ag; 200 Au; G(10,000) Ba; 200 Pb; L(200) Sb; 2000 Sr; 500 Zn	Bar-Cel
224	100 Cu	200 Cu; 200 Pb; 2000 Zn	Py, Bar-Cel, Sph
225	2 Ag; 200 Cu; 50 Mo; 150 Pb; 300 Zn	20 Fe; 10 Ag; 1000 As; 150 Cd; 200 Cu; 200 Pb; 100 W; 7000 Zn	Py
226	0.5 Ag; 500 Cu; 50 Mo; 100 Pb; 200 Zn	50 Mo; L(100) W	
227	70 Cu; 200 Zn	20 Ag; 7000 Zn	
228	100 Cu; 70 Pb; 300 Zn	50 Ag; G(10,000) Ba; L(20) Bi; 200 Cd; 200 Cu; 10,000 Pb	Py, Bar-Cel, Gal, Sph
229	--	--	
230	100 B; 100 Cu; 50 Pb; 200 Zn	G(10,000) Ba; 300 Pb; 700 Zn; 150 Cu	Py, Bar-Cel, Sph
545	L(0.5) Ag; 100 B	G(10,000) Ba; 20 Fe; 3 Ag; 1000 As; 200 Cu; 2000 Pb; 2000 Sr; 5000 Zn; 0.4 μg/pan Au	Py, Bar-Cel
546	L(0.5) Ag; 70 B; 70 Cu; 200 Zn	30 Ag; 500 As; G(10,000) Ba; 300 Bi; 200 Cu; 1000 Pb; 5000 Sr; 5000 Zn	Bar-Cel
547	--	G(10,000) Ba; 50 Mo; 5000 Sr	Py, Bar-Cel
568	--	G(10,000) Ba; 2000 Sr; 0.5 μg/pan Au	Py, Bar-Cel
638	--	30 Fe; G(10,000) Ba; 150 Cu; 10 Mo; 5000 Sr	Py, Bar-Cel
639	200 Zn	G(10,000) Ba; L(50) Cd; 10 Mo	Py, Bar-Cel
640	200 Zn; 70 B	2000 B; G(10,000) Ba	Py, Bar-Cel
808	0.5 Ag; 50 Pb	30 Fe; 30 Ag; 2000 As; 30 Au; G(10,000) Ba; 300 Bi; 500 Cd; 300 Cu; 1000 Pb; 300 Sb; 20,000 Zn; 1 μg/pan Au	Py, Sph
809	--	20 Ag; 2000 As; G(10,000) Ba; 2000 Sr; L(50) Cd; 500 Cu; 1000 Pb; 700 Sb; 5000 Zn	Py, Bar-Cel, Sch-Pow
810	--	20 Fe; G(10,000) Ba; 30 Mo; 2.1 μg/pan Au	Py
811	--	G(10,000) Ba; 3000 Sr	
889	L(0.5) Ag; 70 B; 50 Pb; 200 Zn	G(10,000) Ba; 2000 Sr	Py, Bar-Cel

and contains, in two nonmagnetic heavy-mineral concentrates, 150 and 500 ppm copper, 10 ppm molybdenum, 3,000 and 5 ppm silver, more than 1,000 ppm gold, 300 and 500 ppm lead, 5,000 and 7,000 ppm zinc, 500 and 700 ppm arsenic, 200 ppm antimony, plus boron, barium, strontium, iron, barite-celestite, pyrite, and cinnabar anomalies.

The largest area of pyritic alteration within the study area, as indicated by extensive red color anomalies, lies within and around the San Diego Bay porphyry copper prospect (area 4, plate 2). Concurrent or spatially overlapping periods of alteration and mineralization are indicated by copper-plus-molybdenum anomalies in a stream-sediment sample and a nonmagnetic heavy-mineral concentrate collected at two sites located about 3 km southwest of area 4. The stream-sediment sample contains 100 ppm copper and 20 ppm molybdenum, plus anomalous concentrations of silver,

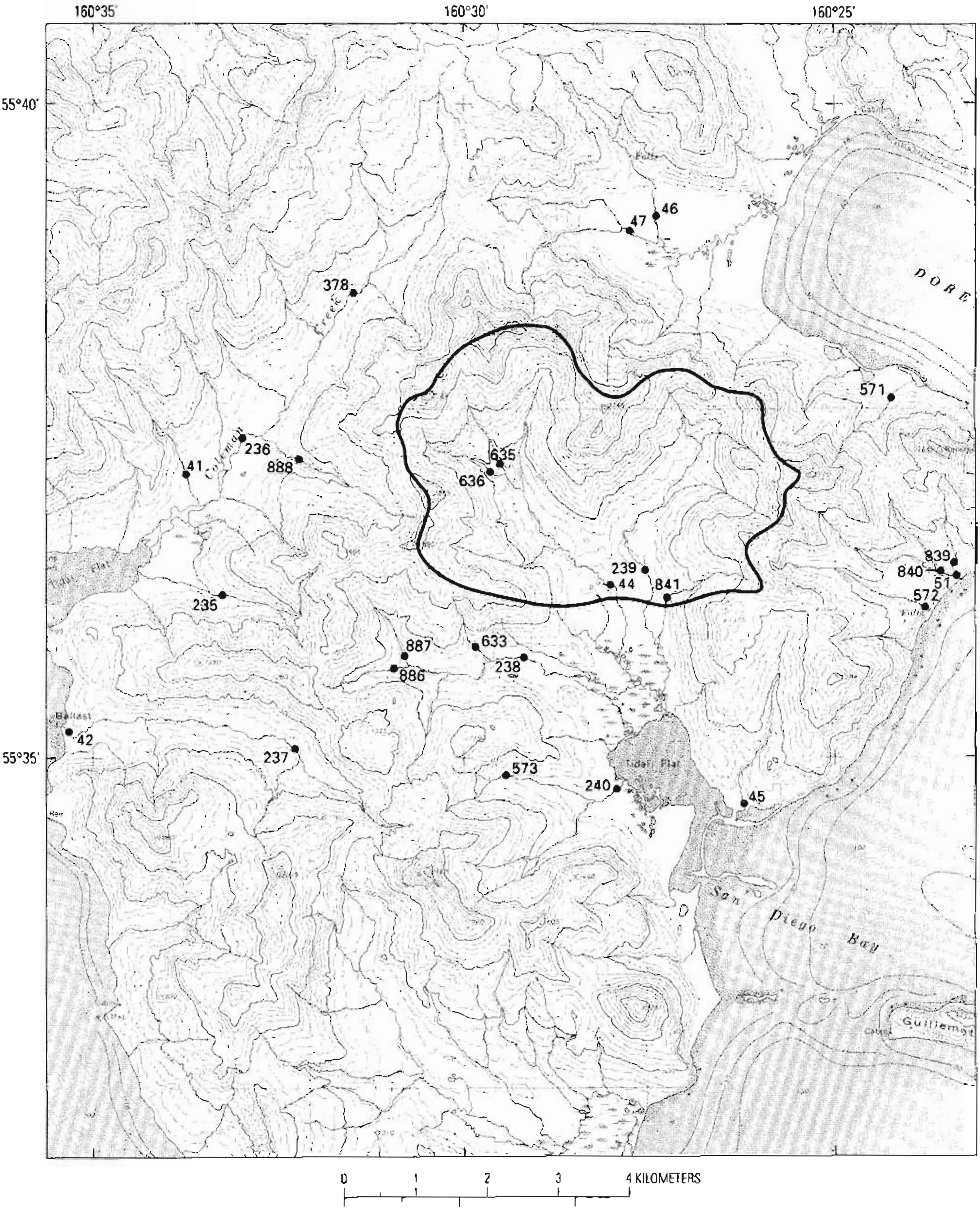


Figure 10. Sample site map for area 4 (plate 2). Drainage basin containing centers of mineralization delineated by solid line. Sample sites shown by solid circle and site number.

Table 11. Summary of selected geochemical anomalies for samples plotted on figure 10 (area 4 on plate 2)

[All values in ppm except for Fe (in percent) and bulk-concentrate Au (in micrograms of gold per pan). The following abbreviations are used: L, detected but less than; G, greater than; Py, pyrite; Bar-Cel, barite-celestite; Gal, galena; Sph, sphalerite; Mol, molybdenite; and Fl, fluorite. Leaders (--), no anomalous data]

Sample site	Anomalous values from sediments	Anomalous values from concentrates	Minerals identified in concentrates
42	50 Pb	1 Ag; 10 Mo; L(50) Cd	Bar-Cel
44	200 Cu; 10 Mo; 70 Pb; 200 Zn; 1.7 Au	20 Fe; 1 Ag; 200 Cd; 10 Mo; 5000 Zn	Py, Sph, Mol
45	70 B	200 Ag; 300 Au; 300 Bi; 200 Pb; 30 Sn	Bar-Cel
46	--	G(10,000) Ba; 2000 Sr	Bar-Cel
47	--	100 Mo	
51	10 Mo	70 Ag; 300 Au; G(10,000) Ba; 2000 Sr	Py, Bar-Cel
235	L(0.5) Ag; 70 B; 100 Cu; 20 Mo; 70 Pb; 10 Sn	1 Ag; 150 Mo; 200 Pb	Py
236	70 Cu; 50 Pb	1 Ag; 3000 Zn	Py, Bar-Cel
237	L(0.5) Ag; 100 Cu; 50 Pb	20 Fe; 1 Ag	Py, Bar-Cel
238	70 Cu; 70 Pb	L(1) Ag; 150 Cu; 1000 Zn	
239	100 Cu; 70 Pb; 200 Zn	L(1) Ag; 200 Cu	Py
240	70 Cu; 70 Pb	50 Ag	
378	--	300 Pb	
571	--	G(10,000) Ba; 30 Mo; 2000 Sr	Bar-Cel, Gal
572	7 Mo	G(10,000) Ba; 5000 Sr; 3000 Zn	Py, Bar-Cel
573	--	30 Fe; G(10,000) Ba; 150 Pb; 2000 Sr	Py
633	L(0.5) Ag; 200 B; 70 Cu; 200 Zn; 70 Pb	30 Fe; L(1) Ag; L(20) Bi; 200 Cu; 20 Mo; 5000 Zn	Py, Bar-Cel, Sph
635	300 Cu; 20 Mo; 50 Pb; 200 Zn	30 Fe; 5 Ag; G(10,000) Ba; 200 Cu; 50 Mo; 200 Pb; 5000 Sr; 10,000 Zn	Py, Bar-Cel, Sph
636	100 Cu; 10 Mo; 50 Pb; 300 Zn	50 Fe; 2 Ag; L(50) Cd; 300 Cu; 50 Mo; 200 Pb 15,000 Zn	Py, Bar-Cel, Sph
839	--	(no spectrographic data)	
840	L(0.5) Ag	(no spectrographic data) 8 μg/pan Au	
841	--	L(1) Ag; G(10,000) Ba; 2000 Bi; 10 Mo; 150 Pb; 2000 Sr; 1000 Zn	Py, Bar-Cel
886	100 B; 50 Pb	150 Pb; 50 Sn; 2000 Sr; 10 Mo	
887	L(0.5) Ag; 200 B; 5 Mo; 50 Pb	20 Fe; 1 Ag; 10 Mo; 50 Cd; 15,000 Zn	Py, Bar-Cel, Sph, Fl, Gal
888	L(0.5) Ag; 70 B; 150 Pb; 500 Zn	G(10,000) Ba; 500 Cd; 5 Ag; 2000 Sr; G(20,000) Zn	Py, Bar-Cel, Sph

lead, tin, and boron. The nonmagnetic heavy-mineral-concentrate sample contains 200 ppm copper and 20 ppm molybdenum associated with silver, lead, zinc, boron, bismuth, iron, and barium, pyrite, sphalerite, galena, fluorite, and barite-celestite anomalies.

About 3 km east of area 5 (plate 2), a drainage basin is represented by a nonmagnetic heavy-mineral concentrate that is anomalous in copper (200 ppm), molybdenum (70 ppm), silver (5 ppm), zinc (3,000 ppm), boron (5,000 ppm), tin (30 ppm), and barium (more than 10,000 ppm). The surrounding drainage basins have barium and low-level molybdenum, lead, silver, boron, and tin anomalies. Barite-celestite, pyrite, and scheelite-powellite were identified in nonmagnetic heavy-mineral concentrates. The area is underlain by Tertiary volcanic rocks and by the Stepovak Formation. Brecciated and altered volcanic rocks were noted in the area.

In the Mount Stepo area, two contiguous drainage basins are represented by low-level copper, molybdenum, lead, and boron anomalies in stream-sediment samples and by arsenic (7,000 ppm), antimony (200 ppm), and low-level copper, molybdenum, silver, and lead anomalies in nonmagnetic

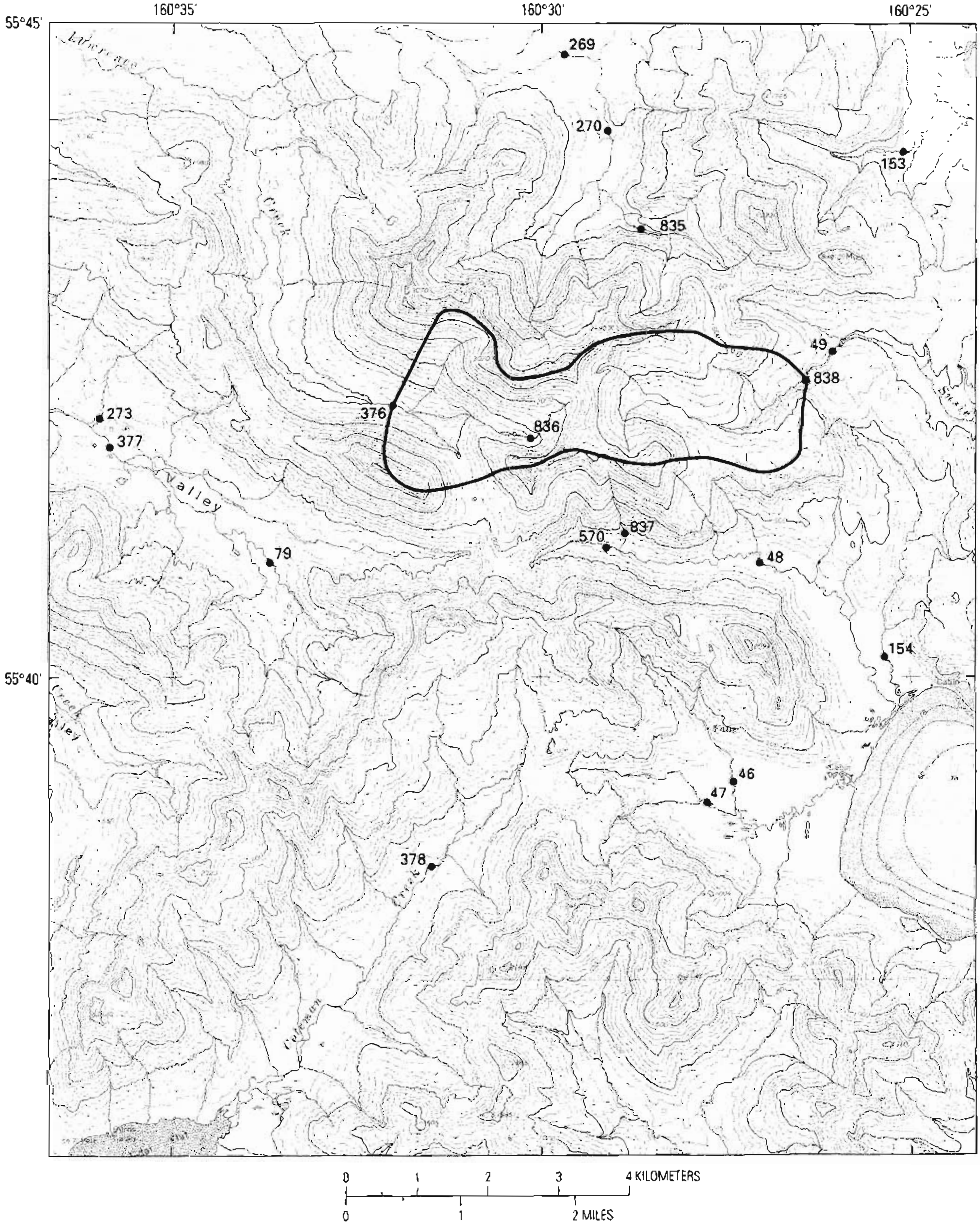


Figure 11. Sample site map for area 5 (plate 2). Drainage basin containing centers of mineralization delineated by solid line. Sample sites shown by solid circle and site number.

Table 12. Summary of selected geochemical anomalies for samples plotted on figure 11 (area 5 on plate 2)

[All values in ppm except for Fe (in percent) and bulk-concentrate Au (in micrograms of gold per pan). The following abbreviations are used: L, detected but less than; G, greater than; Py, pyrite; Bar-Cel, barite-celestite; and Sch-Pow, scheelite-powellite. Leaders (--), no anomalous data]

Sample site	Anomalous values from sediments	Anomalous values from concentrates	Minerals identified in concentrates
46	--	G(10,000) Ba; 2000 Sr	Bar-Cel
47	--	100 Mo	
48	--	20 Ag; 100 Au; G(10,000) Ba	
49	--	G(10,000) Ba; L(50) Cd; 1000 Zn	Py, Bar-Cel
79	--	G(10,000) Ba	Bar-Cel
153	100 B; 50 Pb	L(1) Ag	Py, Bar-Cel
154	100 B	5000 B	
269	0.5 Ag; 150 Pb	20 Ag; 1000 Pb; L(200) Sb	Bar-Cel
270	100 Cu; 70 Pb; 200 Zn	2 Ag; L(500) As; 50 Bi; 300 Pb	Py
273	--	--	
376	200 B; 100 Cu; 15 Mo	20 Fe; 200 Cu; 20 Mo; 1000 W	Py, Bar-Cel, Sch-Pow
377	--	--	
378	--	300 Pb	
570	--	G(10,000) Ba; 3000 Sr	Bar-Cel
835	--	30 Fe; 15 Ag; 150 Cu; 3000 Pb 2.8 µg/pan Au	Py, Bar-Cel
836	L(0.5) Ag	20 Fe; 10 Ag; 150 Cu; 200 Pb; 1.1 µg/pan Au	
837	--	20 Fe; L(1) Ag; 3000 As; G(10,000) Ba; 500 Cu; 2000 Sr	Py, Bar-Cel
838	--	30 Fe; L(1) Ag; G(10,000) Ba; 150 Cu; 20 Mo; 200 Pb; 2000 Sr; 0.5 µg/pan Au	Py, Bar-Cel

heavy-mineral concentrates. Surrounding drainage basins contain low-level copper, molybdenum, and boron anomalies in stream-sediment samples and low-level copper, molybdenum, lead, zinc, boron, strontium, tungsten, and barium anomalies in nonmagnetic heavy-mineral concentrates. Pyrite and barite-celestite are also present in nonmagnetic heavy-mineral concentrates. Tertiary volcanic and intrusive rocks are in contact with the Stepovak Formation in this area and altered rocks were noted at some sites.

About 5 km north of Mount Stepo, a drainage basin has low-level copper, molybdenum, lead, and zinc anomalies in a stream-sediment sample. Surrounding drainage basins are anomalous in copper, molybdenum, silver, lead, arsenic, cadmium, barium, pyrite, and barite-celestite. This area is underlain by Tertiary and Quaternary volcanic rocks that have, in part, been brecciated and silicically and propylitically altered.

Two drainage basins, underlain by Tertiary and Quaternary volcanic rocks and by the Bear Lake Formation, are located along the north side of the Aleutian Range and have copper and molybdenum anomalies in nonmagnetic heavy-mineral concentrates. One drainage basin, located about 6 km northeast of Left Head, is anomalous in copper, molybdenum, silver, arsenic, strontium, and barium. Surrounding drainage basins are anomalous in zinc, tin, arsenic, barium, pyrite, and barite-celestite. Propylitically altered volcanic rocks were noted. The drainage basin located at the head of Milky Creek, east of Bear Lake, is anomalous in copper, molybdenum, lead, arsenic, and iron, and is surrounded by drainage basins anomalous in copper, silver, tin, arsenic, bismuth, iron, barite-celestite, and pyrite. This drainage basin and the drainage basin across the Aleutian Range to the south contain altered rocks with the highest pyrite content noted in the study area.

Between Orzinski Bay and Clark Bay, an area underlain by the Stepovak Formation, a site contains 70 ppm copper in a stream-sediment sample and 20 ppm molybdenum and more than 5,000 ppm boron in a nonmagnetic heavy-mineral concentrate. Sericitically altered zones and basalt(?) dikes in sandstone crop out in this area (Wilson and others, 1988). Rock samples collected from this site were anomalous in arsenic and antimony.

A stream-sediment copper-plus-molybdenum anomaly occurs at a site on the west side of Red Hill in an area of iron-oxide-stained Tertiary volcanic rocks. Surrounding sites are anomalous in copper, silver, zinc, boron, cadmium,

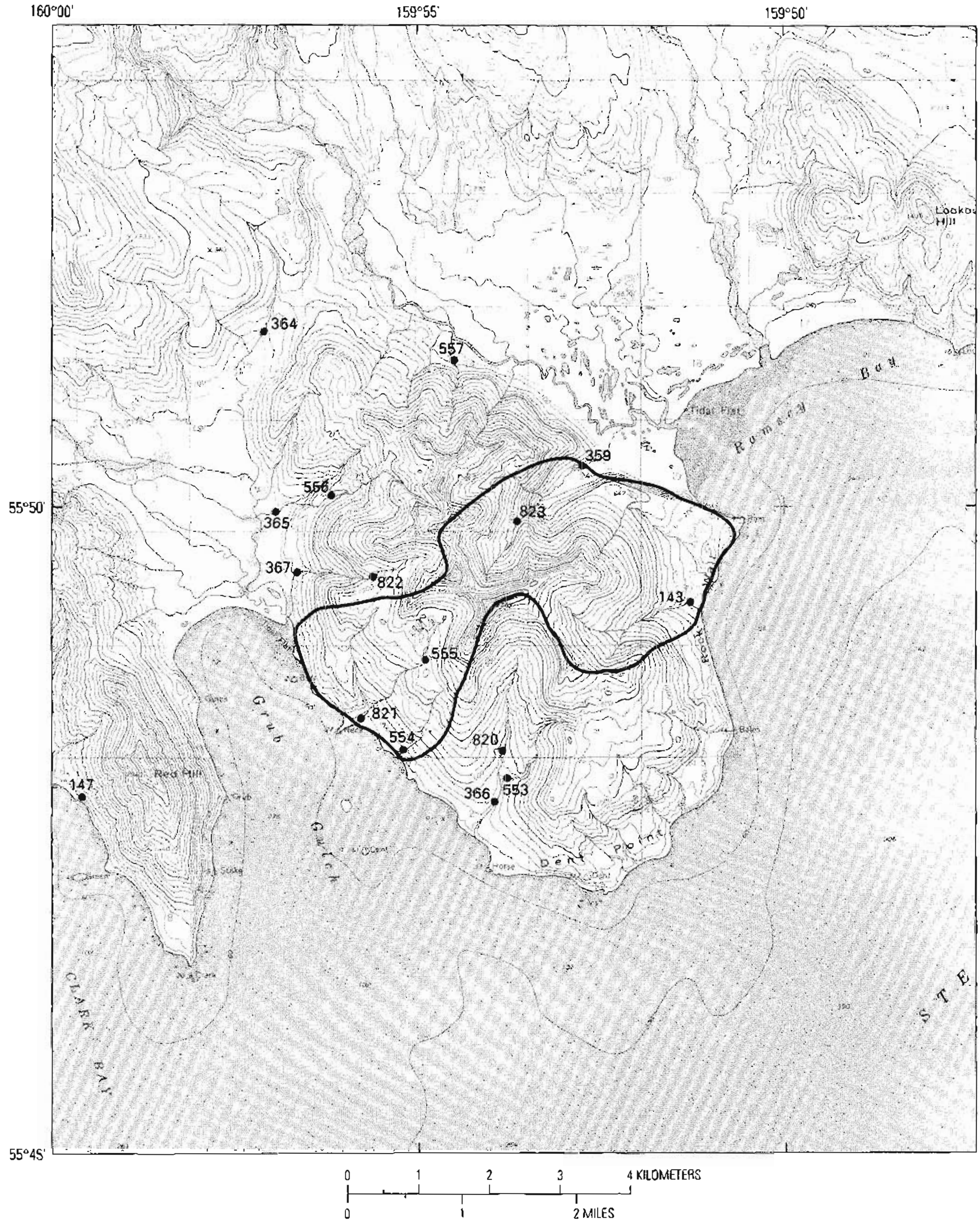


Figure 12. Sample site map for area 6 (plate 2). Drainage basin containing centers of mineralization delineated by solid line. Sample sites shown by solid circle and site number.

Table 13. Summary of selected geochemical anomalies for samples plotted on figure 12 (area 6 on plate 2)

[All values in ppm except for Fe (in percent) and bulk-concentrate Au (in micrograms of gold per pan). The following abbreviations are used: L, detected but less than; G, greater than; Py, pyrite; Bar-Cel, barite-celestite; Gal, galena; and Sph, sphalerite. Leaders (--), no anomalous data]

Sample site	Anomalous values from sediments	Anomalous values from concentrates	Minerals identified in concentrates
143	50 Pb	1 Ag; G(10,000) Ba; 200 Cd; 150 Cu; 50 Mo; 2000 Sr	Py, Bar-Cel
147	1 Ag; 100 Cu; 10 Mo	10 Mo; 100 W	Py
359	500 Cu; 20 Mo	20 Fe; 5 Ag; L(500) As; G(10,000) Ba; 20 Bi; 200 Cu; 20 Mo	Py, Bar-Cel
364	100 Cu; 200 Zn	--	
365	--	200 Pb; 70 Sn	Py
366	--	5000 B; 70 Bi; 200 Mo; 1000 Pb	Py
367	L(0.5) Ag; 200 Cu; 100 Pb; 0.02 Au	50 Ag; L(500) As; 100 Au; 1000 Cd; 500 Cu; 1000 Pb; L(200) Sb; 150 Sn; L(100) W; 7000 Zn	Py, Bar-Cel, Sph
553	--	3000 B; 30 Mo; 500 Pb	
554	--	(no spectrographic data)	
555	L(0.5) Ag	20 Mo	Py
556	L(0.5) Ag; 70 Cu; 50 Pb	20 Fe; 0.5 Ag; 500 As; G(10,000) Ba; 200 Cu; 20,000 Pb	Py, Bar-Cel
557	L(0.5) Ag	G(10,000) Ba; 10 Mo; 500 Pb; 5000 Sr; 5000 Zn	Py, Bar-Cel
820	--	100 Mo; 700 Pb	Py
821	50 Pb	20 Ag; 1000 As; 50 Bi; 700 Cu; 150 Mo; 15,000 Pb; 2000 Zn	Py, Gal
822	0.5 Ag; 100 Cu; 10 Mo; 50 Pb	20 Fe; 70 μg/pan Au	Py
823	0.5 Ag; 150 Cu; 50 Mo	30 Fe; 150 Cu; 50 Mo; 31 μg/pan Au	Py, Bar-Cel

strontium, barium, pyrite, sphalerite, and barite-celestite. This area may be an extension of the mineralization center at Grub Gulch (area 6, plate 2), discussed previously.

A nonmagnetic heavy-mineral concentrate collected from a drainage basin located about 5 km north of area 7 (plate 2) contains 200 ppm copper, 30 ppm molybdenum, 5,000 ppm boron, and 30 percent iron. Nearby drainage basins are anomalous in copper, zinc, iron, boron, barium, pyrite, and cinnabar. The area is underlain by the Meshik Volcanics.

A drainage basin on Pinusuk Island is underlain by the Meshik Volcanics and is represented by 700 ppm copper, 10 ppm molybdenum, and more than 5,000 ppm boron in a nonmagnetic heavy-mineral concentrate.

Two rock samples collected on Mitrofania Island and another collected south of Herring Lagoon on the mainland are quartz-sulfide vein samples collected from areas of contact-metamorphosed rocks associated with the Devils batholith. Rock samples collected in these areas are anomalous in copper, molybdenum, silver, gold, lead, zinc, boron, bismuth, arsenic, antimony, and cadmium.

Both Unga Island and Popof Island have four centers of copper-molybdenum mineralization in addition to areas 9 and 10 (plate 2) that were discussed previously. From north to south on Unga Island, these include the area of gold and mercury anomalies east of the mouth of Zachary Bay (area 3, plate 1), underlain by the Popof volcanic rocks. An andesite sample collected in this area from an iron-oxide-stained fracture zone contains 150 ppm copper, 10 ppm molybdenum, 200 ppm zinc, 500 ppm boron, and 50 ppm arsenic. Cinnabar, molybdenite, and pyrite were noted in nonmagnetic heavy-mineral concentrates.

To the south, at Quartz Point, a nonmagnetic heavy-mineral concentrate contains 150 ppm copper, 10 ppm molybdenum, 2,000 ppm zinc, 2,000 ppm arsenic, and pyrite. Iron-oxide staining and large masses of chalcedony occur at this site.

About 2 km southwest of the head of Baralof Bay and adjacent to the Shumagin gold deposit, a drainage basin contains 70 ppm copper, 5 ppm molybdenum, and 50 ppm lead in a stream-sediment sample and 1,000 ppm zinc, 50 ppm cadmium, and more than 10,000 ppm barium in a nonmagnetic heavy-mineral concentrate.

Anomalous concentrations of copper plus molybdenum were determined in two rock samples collected along the east side of Acheredin Bay. An altered volcanic-rock sample

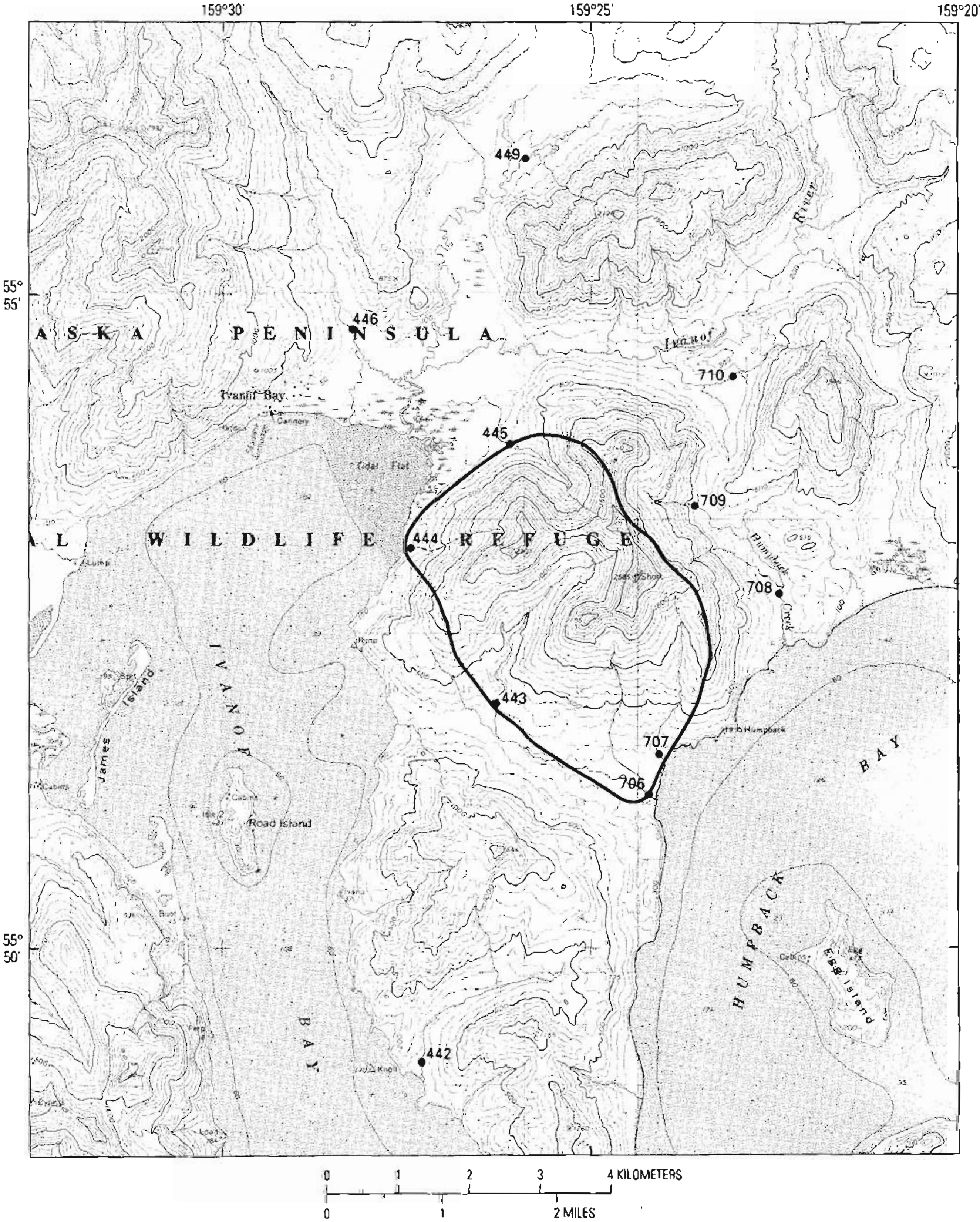


Figure 13. Sample site map for area 7 (plate 2). Drainage basin containing centers of mineralization delineated by solid line. Sample sites shown by solid circle and site number.

Table 14. Summary of selected geochemical anomalies for samples plotted on figure 13 (area 7 on plate 2)

[All values in ppm except for Fe (in percent) and bulk-concentrate Au (in micrograms of gold per pan). The following abbreviations are used: L, detected but less than; Py, pyrite; Gal, galena; Mol, molybdenite; and Cp, chalcopyrite. Leaders (--), no anomalous data]

Sample site	Anomalous values from sediments	Anomalous values from concentrates	Minerals identified in concentrates
442	--	--	
443	L(0.5) Ag; 150 Cu; 20 Mo	30 Fe; 10 Ag; 200 Bi; 500 Cu; 100 Mo; 1000 Zn; 89 µg/pan Au	Py
444	0.7 Ag; 200 Cu; 70 Mo	70 Ag; 1000 As; 20,000 Pb	Py
445	--	50 Fe; 3 Ag; 2000 As; 30 Bi; 700 Cu; 150 Mo; 9.1 µg/pan Au	Py, Mol
446	70 Cu	5000 B; 1.5 µg/pan Au	Py
449	--	2000 Zn	
706	100 Cu; 5 Mo; 0.002 Au	5 Ag; 20 Au; 150 Cu; 100 Mo; 50 Sn; 39 µg/pan Au	Py, Cp, Mol
707	--	30 Fe; 2 Ag; 1000 As; 200 Cu; 1000 Pb; 1.5 µg/pan Au	Py, Cp, Mol
708	--	--	
709	L(0.5) Ag	50 Ag; 5000 Pb; 30 Sn; 0.3 µg/pan Au	Py, Gal
710	--	14 µg/pan Au	

with 50 percent sulfides contains 500 ppm copper, 5 ppm molybdenum, 70 ppm lead, 500 ppm zinc, 10 ppm silver, 0.15 ppm gold, more than 6 ppm mercury, 150 ppm arsenic, and 20 percent iron. The other mineralized rock sample contains 500 ppm copper, 50 ppm molybdenum, 70 ppm lead, detectable silver, 50 ppm tin, 150 ppm bismuth, 100 ppm antimony, and 250 ppm arsenic. A nonmagnetic heavy-mineral concentrate contains 10 ppm molybdenum and a stream-sediment sample contains 200 ppm copper; these samples are associated with anomalous concentrations of silver, gold, lead, zinc, bismuth, and tungsten in this area.

On Popof Island, from west to east, a site at Sand Point contains 5 ppm molybdenum, 100 ppm lead, and 200 ppm zinc in a stream-sediment sample and 1,500 ppm copper, 1,500 ppm silver, more than 1,000 ppm gold, more than 50,000 ppm lead, 2,000 ppm tin, 30 ppm bismuth, and 1,500 ppm antimony in a nonmagnetic heavy-mineral concentrate. The samples at this site were collected from active beach sediments that may have been moved westward by longshore currents.

A site about 4 km to the southeast may be closer to the source of the Sand Point samples. A stream-sediment sample collected at this previously described precious-metal site contains 70 ppm copper and 10 ppm molybdenum. Native gold and molybdenite were noted in nonmagnetic heavy-mineral concentrates.

A sample of brecciated andesite collected about 2 km northwest of area 10 (plate 2) contains 150 ppm copper, 10 ppm molybdenum, 200 ppm zinc, 1 ppm silver, 600 ppm arsenic, and 20 percent iron. Propylitically altered, quartz-rich intrusive rocks were seen in this area.

About 2 km southeast of area 10 (plate 2), a stream-sediment sample contains 70 ppm copper, 5 ppm molybdenum, and 200 ppm zinc, and a nonmagnetic heavy-mineral concentrate contains 100 ppm tungsten, pyrite, and cinnabar. Altered rocks were seen in the area.

Three stream-sediment samples, collected from drainage basins draining the Shumagin Formation on Nagai Island, also contained anomalous concentrations of copper plus molybdenum. On the east side of Eagle Harbor, a stream-sediment sample contains 70 ppm copper, 5 ppm molybdenum, 200 ppm zinc, and 70 ppm boron, and a nonmagnetic heavy-mineral concentrate collected from the same site contains 200 ppm copper, 70 ppm silver, and 200 ppm gold. A stream-sediment sample collected 2 km north of Caton Cove on the east side of Sanborn Harbor contains 70 ppm copper, 5 ppm molybdenum, and 200 ppm zinc. A site at the northeast side of the mouth of East Bight contains 70 ppm copper, 5 ppm molybdenum, 200 ppm zinc, and 100 ppm boron. No color anomalies or other evidence of extensive hydrothermal alteration were noted at any of the sites on Nagai Island or on the outer Shumagin Islands.

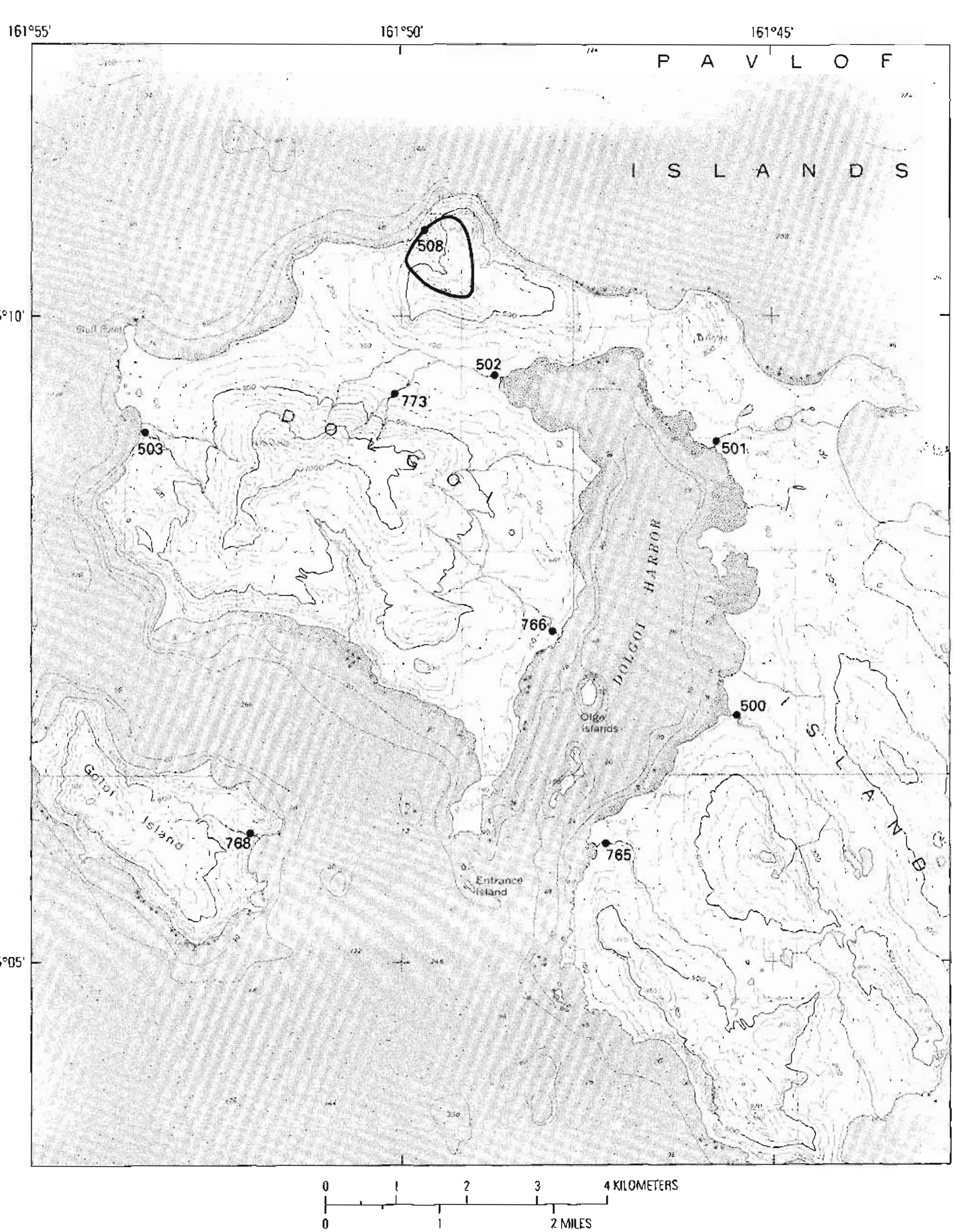


Figure 14. Sample site map for area 8 (plate 2). Drainage basin containing centers of mineralization delineated by solid line. Sample sites shown by solid circle and site number.

Table 15. Summary of selected geochemical anomalies for samples plotted on figure 14 (area 8 on plate 2)

[All values in ppm except for Fe (in percent) and bulk-concentrate Au (in micrograms of gold per pan). The following abbreviations are used: G, greater than; Py, pyrite; Bar-Cel, barite-celestite; Sph, sphalerite; and Cin, cinnabar. Leaders (--), no anomalous data]

Sample site	Anomalous values from sediments	Anomalous values from concentrates	Minerals identified in concentrates
500	--	--	
501	--	--	Cin
502	--	--	
503	--	30 Bi; 20,000 Pb	
508	0.5 Ag; 150 Cu; 50 Mo; 70 Pb; 0.004 Au	5 Ag; 200 Cu; 20 Mo; 700 Pb; 150 Sn; 10,000 Zn; 1000 B	Py
765	--	--	
766	--	G(10,000) Ba	Cin
768	--	--	
773	0.7 Ag; 150 Cu; 50 Pb; 200 Zn; 0.004 Au	30 Fe; 3000 Ag; 100 Au; G(10,000) Ba; 700 Cd; 200 Cu; G(20,000) Zn; 2.5 μg/pan Au	Py, Bar-Cel, Sph

CONCLUSIONS

Examination of geological and geochemical evidence indicates that the Port Moller study area has potential for the discovery of additional porphyry copper or molybdenum deposits and for additional epithermal gold deposits. Gold anomalies, especially those associated with quartz-sulfide veins, are the best indicators for areas with potential for epithermal gold deposits. The copper- and molybdenum-rich porphyry sulfide systems are best indicated by extensive zones of hydrothermally altered rocks—these zones of altered rocks are generally spatially associated with intrusive rocks of intermediate composition and with one or more drainage basins that have copper and molybdenum anomalies in both stream-sediment samples and nonmagnetic heavy-mineral concentrates. These drainage basins are generally surrounded by drainage basins that have stream-sediment samples plus panned concentrates that contain anomalous concentrations of copper, lead, zinc, silver, gold, boron, tin, arsenic, antimony, bismuth, cadmium, iron, tungsten, strontium, or barium. Plates 1 and 2 show geochemically anomalous areas that include, but are not limited to, areas containing known mineral prospects. These maps indicate favorable new targets for mineral exploration.

REFERENCES CITED

Angeloni, L.M., Wilson, F.H., and Sutley, S.J., 1985, Map and tables showing preliminary rock geochemical data, Port Moller, Stepovak Bay, and Simeonof Island quadrangles, Alaska: U.S. Geological Survey Open-File Report 85–470, 179 p.

Arbogast, B.F., Bailey, E.A., and Frisken, J.G., 1987, Analytical results and sample locality maps of stream-sediment, heavy-mineral-concentrate, and rock samples from the Port Moller, Stepovak Bay, and Simeonof Island quadrangles, Alaska: U.S. Geological Survey Open-File Report 87–502, 122p.

Armstrong, R.L., Harakal, J.E., and Hollister, V.F., 1976, Age determination of late Cenozoic porphyry copper deposits of the North American Cordillera: Institute of Mining and Metallurgical Transactions, SectionB, v. 85, p. 239–244.

Atwood, W.W., 1911, Geology and mineral resources of parts of the Alaska Peninsula: U.S. Geological Survey Bulletin 467, 137 p.

Burk, C.A., 1965, Geology of the Alaska Peninsula—Island arc and continental margin: Geological Society of America Memoir 99, 250 p., scales 1:250,000 and 1:500,000.

Christie, J.S., 1975, Pyramid project Aleut-Quintana-Duval joint venture report on 1975 drill programme: Quintana Minerals Corporation report (unpublished), [obtained from Aleut Corporation], 17 p.

Christie, J.S., and Wolfhard, M.R., 1977, Pyramid porphyry copper-molybdenum prospect, Alaska [abs.]: Geological Asssociation of Canada—Society of Economic Geologists, annual meeting, Vancouver, Canada, 1977, Program with Abstracts, v. 2, p. 12.

Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.

Crock, J.G., Briggs, P.H., Jackson, L.L., and Lichte, F.E., 1987, Analytical methods for the analysis of stream sediments and rocks from wilderness study areas: U.S. Geological Survey Open-File Report 87–84, 35 p.

Detterman, R.L., Case, J.E., Miller, J.W., Wilson, F.H., and Yount, M.E., in press, Stratigraphic framework of the Alaska Peninsula: U.S. Geological Survey Bulletin 1969.

Frisken, J.G., and Arbogast, B.F., 1991a, Map showing the distribution of anomalous concentrations of selected elements determined in stream sediments from the Port Moller, Stepovak Bay, and Simeonof Island quadrangles, Alaska Peninsula, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF–2155–B, scale 1:250,000.

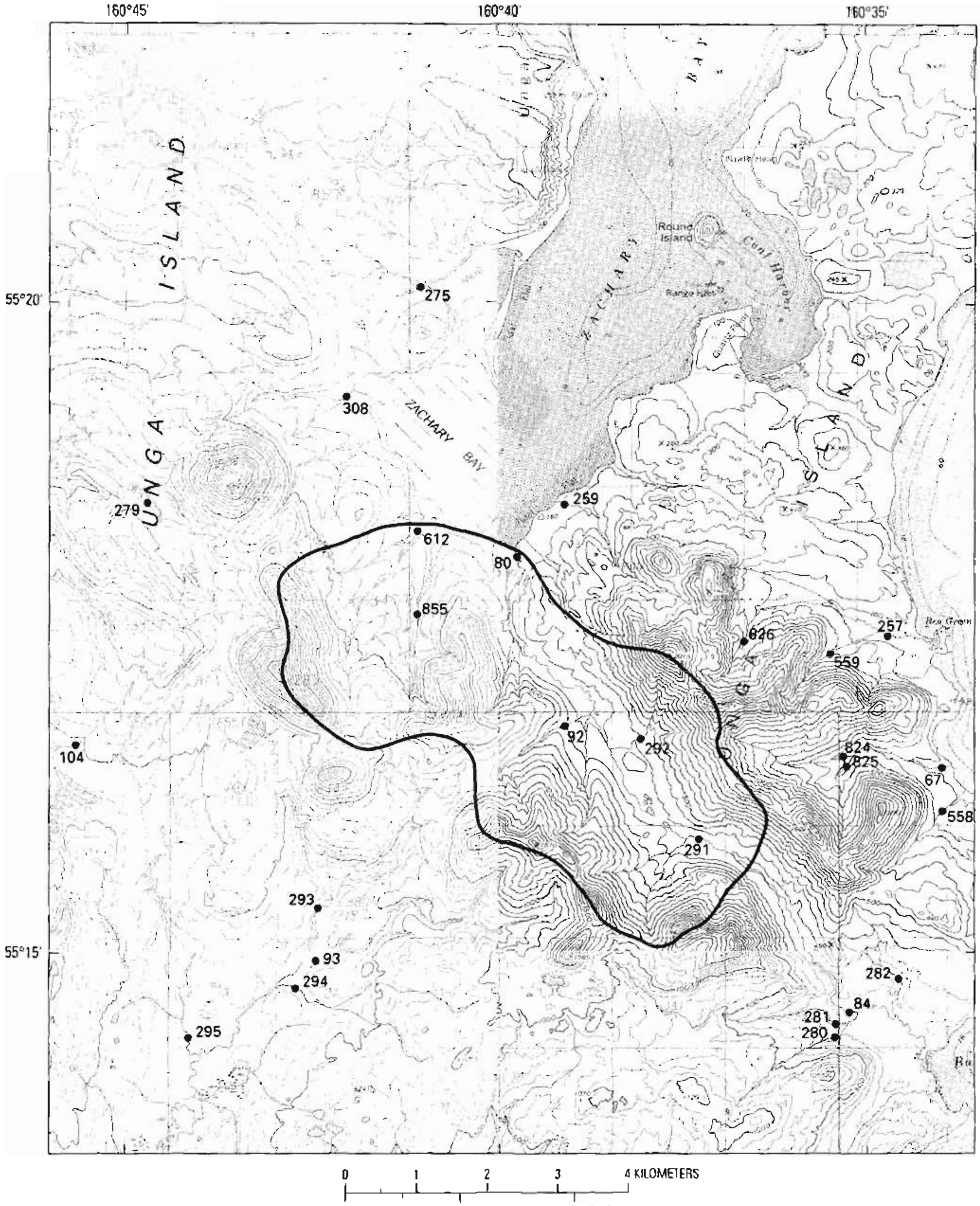


Figure 15. Sample site map for area 9 (plate 2). Drainage basin containing centers of mineralization delineated by solid line. Sample sites shown by solid circle and site number.

Table 16. Summary of selected geochemical anomalies for samples plotted on figure 15 (area 9 on plate 2)

[All values in ppm except for Fe (in percent) and bulk-concentrate Au (in micrograms of gold per pan). The following abbreviations are used: L, detected but less than; G, greater than; Py, pyrite; Bar-Cel, barite-celestite; and Mol, molybdenite. Leaders (--), no anomalous data]

Sample site	Anomalous values from sediments	Anomalous values from concentrates	Minerals identified in concentrates
67	--	--	
80	150 Cu; 0.004 Au	20 Mo	
84	70 Pb; 0.002 Au	L(50) Cd; 200 Cu; 700 Zn	Py
92	200 Cu; 50 Pb; 2.4 Au	2 Ag; 70 Cd; 500 Cu; 50 Mo; 1500 Zn	Py, Mol
93	0.002 Au	--	
104	--	--	Mol
257	--	--	
259	--	L(1) Ag; G(10,000) Ba; 500 Pb; 2000 Sr; 1000 Zn	Bar-Cel
275	--	--	
279	--	--	
280	0.15 Au	L(1) Ag; G(10,000) Ba;	Bar-Cel
281	100 Cu; 100 Pb; 200 Zn	1 Ag; 200 Cu; 2000 Zn; L(500) As	Py, Bar-Cel
282	70 Cu	--	
291	150 Cu; 100 Pb; 0.002 Au	L(1) Ag; 2000 Zn	
292	100 Cu; 10 Mo; 50 Pb; 0.002 Au	20 Fe; 1 Ag; 700 Zn	Py
293	50 Pb	--	
294	0.002 Au	--	
295	--	--	
308	--	--	
558	--	G(10,000) Ba; 20 Mo	
559	--	20 Fe; L(1) Ag; 700 As; G(10,000) Ba;30 Mo; 3000 Sr; 4.1 μg/pan Au	Py, Bar-Cel
612	70 Cu; 5 Mo; 200 Zn	1000 Pb; 50 Sn	Py, Gold
824	--	2 Ag; 150 Cu	Py
825	0.25 Au	3 μg/pan Au	
826	L(0.5) Ag	(no spectrographic data)	
855	5 Mo; 500 Zn	7 Ag; 2000 Zn	

Frisken, J.G., and Arbogast, B.F., 1991b, Maps showing the distribution of anomalous concentrations of selected elements and minerals determined in nonmagnetic heavy-mineral concentrates from the Port Moller, Stepovak Bay, and Simeonof Island quadrangles, Alaska Peninsula, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2155-C, scale 1:250,000.

Frisken, J.G., and Kelley, D.A., 1991, Maps showing the distribution of gold determined in various sample media collected from the Port Moller, Stepovak Bay, and Simeonof Island quadrangles, Alaska Peninsula, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2155-D, scale 1:250,000.

Green, C.B., Bundtzen, T.K., Peterson, R.J., Seward, A.F., Deagan, J.R., and Burton, J.E., 1989, Alaska's mineral industry, 1988: State of Alaska Division of Geological and Geophysical Surveys Special Report 43, p. 66 and 68.

Grimes, D.J., and Marranzino, A.P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.

Kennedy, G.C., and Waldron, H.H., 1955, Geology of the Pavlof Volcano and vicinity, Alaska: U.S. Geological Survey Bulletin 1028-A, 19 p., scale 1:100,000.

MacKevett, E.M., Jr., and Holloway, C.D., 1977, Map showing metalliferous mineral deposits in the western part of southern Alaska: U.S. Geological Survey Open-File Report 77-169-F, 38 p., scale 1:1,000,000.

Meier, A.L., 1980, Flameless atomic-absorption determination of gold in geologic materials: Journal of Geochemical Exploration, v. 13, p. 77-85.

Moore, J.C., 1974, Geologic and structural map of part of the outer Shumagin Islands, southwestern Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-815, scale 1:63,360.

Nokleberg, W.J., Bundtzen, T.K. Berg, H.C., Brew, D.A., Grybeck, Donald, Robinson, M.S., Smith, T.E., and Yeend, Warren, 1987, Significant metalliferous lode deposits and placer districts of Alaska: U.S. Geological Survey Bulletin 1786, p. 41-42.

Wahrhaftig, Clyde, 1965, Physiographic divisions of Alaska: U.S. Geological Survey Professional Paper 482, 52 p.

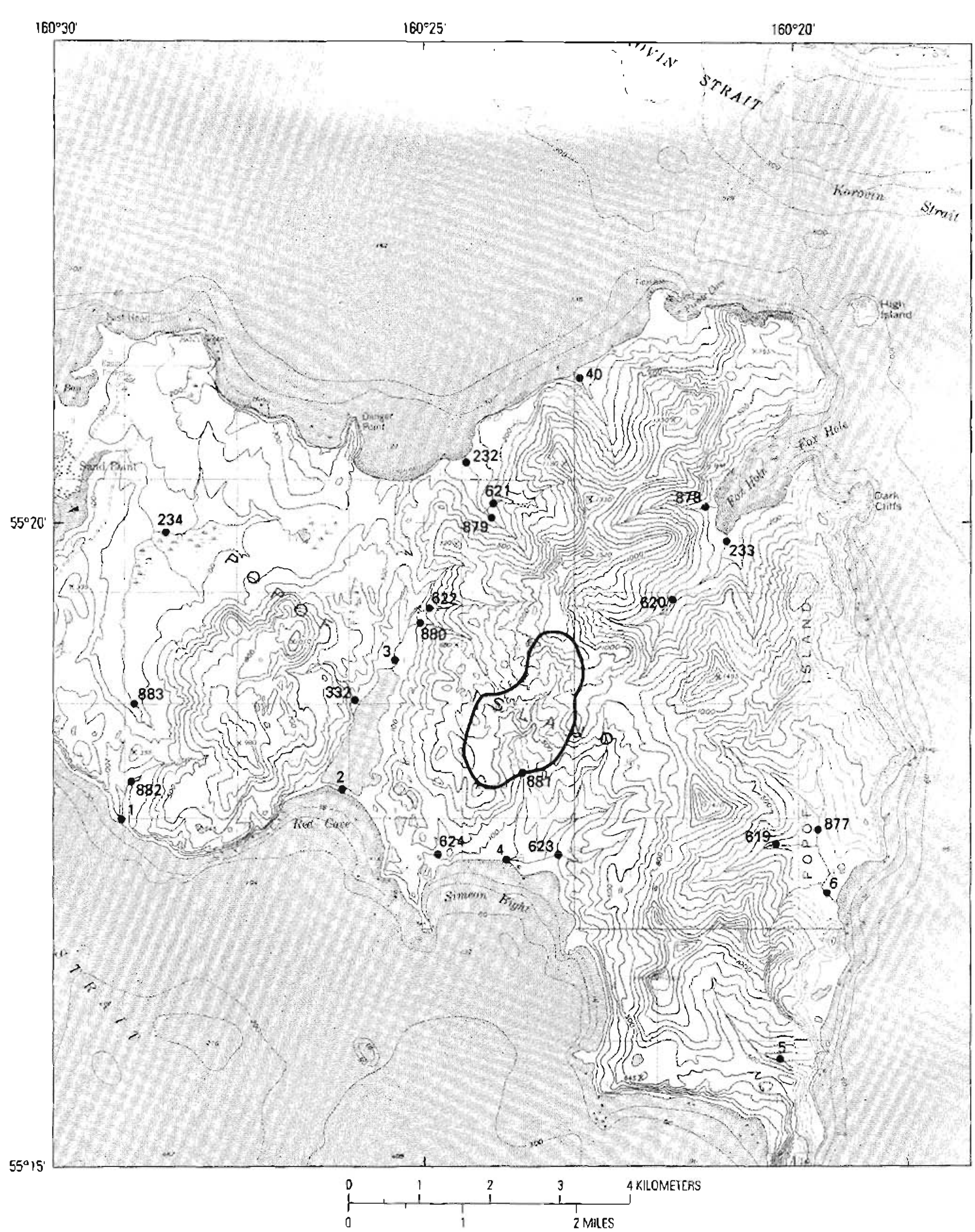


Figure 16. Sample site map for area 10 (plate 2). Drainage basin containing centers of mineralization delineated by solid line. Sample sites shown by solid circle and site number.

Table 17. Summary of selected geochemical anomalies for samples plotted on figure 16 (area 10 on plate 2)

[All values in ppm except for Fe (in percent). The following abbreviations are used: L, detected but less than; G, greater than; Py, pyrite; Bar-Cel, barite-celestite; Sph, sphalerite; Cin, cinnabar; Mol, molybdenite; and Fl, fluorite. Leaders (--), no anomalous data]

Sample site	Anomalous values from sediments	Anomalous values from concentrates	Minerals identified in concentrates
1	70 Cu; 10 Mo; 1.2 Au	500 Ag; 1000 Au; 100 Sn	Mol, Gold
2	(no sample)	L(1) Ag; G(10,000) Ba; 150 Cu; 50 Sn	Bar-Cel
3	70 Cu	--	Cin
4	--	--	
5	--	--	
6	--	--	
40	100 Cu; 200 Zn	--	
232	100 Cu	--	
233	100 Cu; 200 Zn	200 Pb	
234	--	2000 As; G(10,000) Ba; 10 Mo; 1000 Zn	Py, Bar-Cel
332	--	--	Mol
619	70 Cu; 5 Mo; 200 Zn	100 W	Py, Cin
620	200 Zn	L(1) Ag; 1000 Pb; 100 W	Py
621	70 Cu; 200 Zn	20 Ag; 3000 Pb	
622	70 Cu; 200 Zn	(no sample)	
623	200 Zn	--	Cin
624	5 Mo; 200 Zn; 0.002 Au	10 Mo	Py, Cin
877	200 Zn	1500 Zn	Py, Cin
878	200 Zn	2000 Sr	
879	70 Cu; 200 Zn	2000 Sr	Py
880	100 B; 100 Cu; 200 Zn	200 Cu; 1000 Zn	Py
881	100 Cu; 7 Mo; 300 Zn	30 Fe; 1 Ag; 1000 As; G(10,000) Ba; 100 Cd; 700 Cu; 15 Mo; 2000 Sr; G(20,000) Zn	Py, Bar-Cel Sph, Fl
882	70 Cu; 200 Zn	--	
883	5 Mo; 500 Zn	(no sample)	

Wilson, F.H., 1985, The Meshik arc—an Eocene to earliest Miocene magmatic arc on the Alaska Peninsula: Alaska Division of Geological and Geophysical Surveys Professional Report 88, 14 p.

Wilson, F.H., and Cox, D.P., 1983, Geochronology, geochemistry, and tectonic environment of porphyry mineralization in the central Alaska Peninsula: U.S. Geological Survey Open-File Report 83–783, 24 p.

Wilson, F.H., Detterman, R.L., and Harris, E.E., 1991, Generalized geologic map of the Port Moller, Stepovak Bay, and Simeonof Island quadrangles, Alaska Peninsula, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF–2155–A, scale 1:250,000.

Wilson, F.H., Detterman, R.L., Miller, J.W., and Case, J.E., in press, Geologic map of the Port Moller, Stepovak Bay, and Simeonof Island quadrangles, Alaska Peninsula, Alsaka: U.S. Geological Survey Miscellaneous Investigations Series Map I–2272, scale 1:250,000.

Wilson, F.H., Harris, E.E., and Bailey, E.A., 1987, Preliminary analytical results and sample locality map for rock samples collected in 1985 and 1986, Port Moller and Stepovak Bay quadrangles, Alaska: U.S. Geological Survey Open-File Report 87–497, 44 p.

Wilson, F.H., White, W.H., and DuBois, G.D., 1988, Brief descriptions of mines, prospects, and mineral occurrences in the Port Moller and Stepovak Bay quadrangles, Alaska Peninsula: U.S. Geological Survey Open-File Report 88–666, 132 p.

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