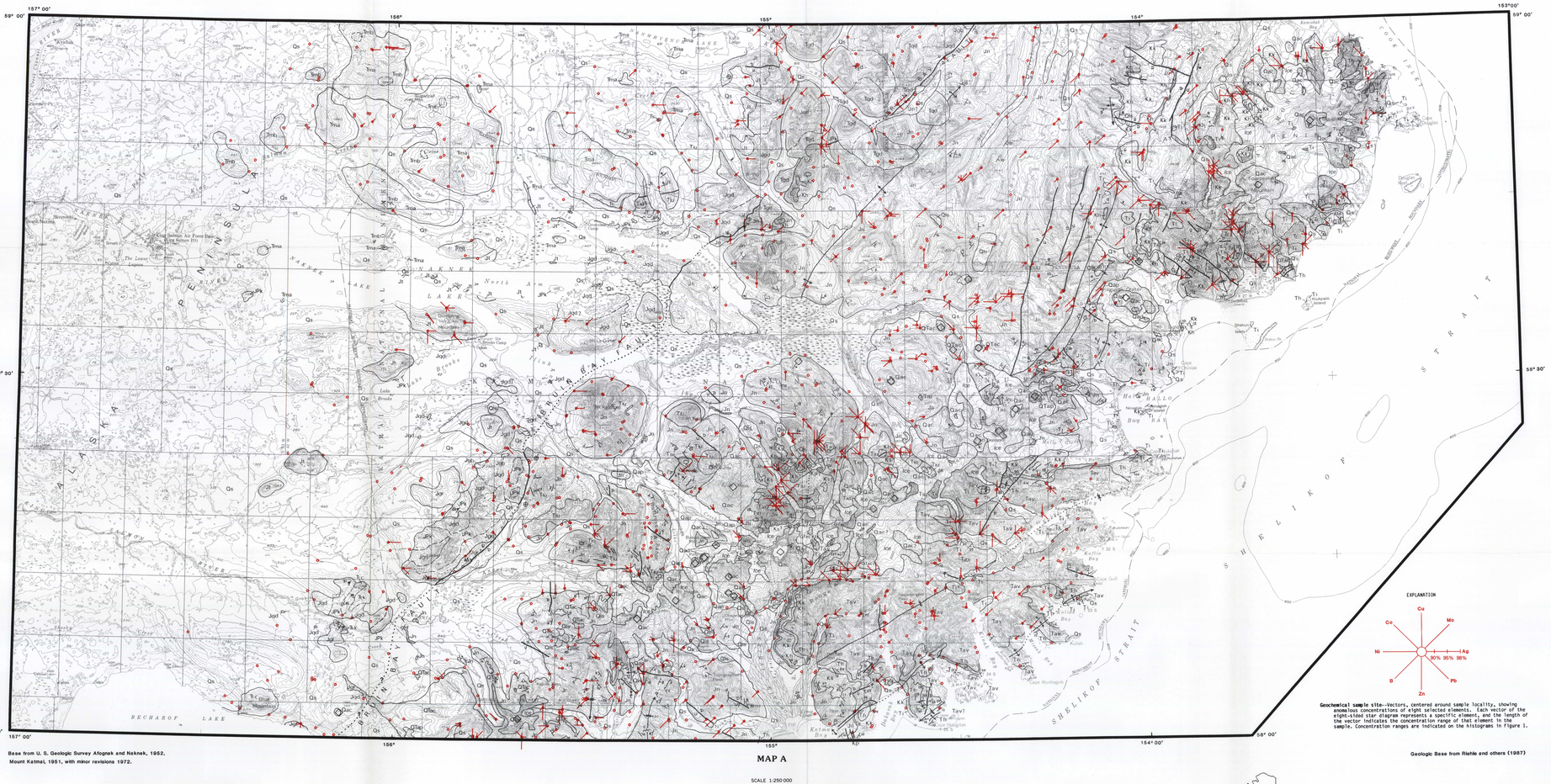

Base from U. S. Geologic Survey Afognak and Naknek, 1952, Mount Katmai, 1951, with minor revisions 1972.

Geochemical sample site--Vectors, centered around sample locality, showing anomalous concentrations of eight selected elements. Each vector of the eight-sided star diagram represents a specific element, and the length of the vector indicates the concentration range of that element in the sample. Concentration ranges are indicated on the histograms in figure 1.

Geologic Base from Riehle and others (1987)

MAP A

SCALE 1:250 000

5 0 5 10 15 MILES

5 0 5 10 15 KILOMETERS

CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

CORRELATION OF MAP UNITS

Surficial Deposits and Sedimentary Rocks	Volcanic Rocks	Intrusive Rocks	Metamorphic Rocks		
Qh, unconformity	Qhs, Qac, Qap, Qad, QTac			Holocene and Pleistocene	QUATERNARY
					QUATERNARY AND/OR TERTIARY
Th, unconformity	Ts, Tav	d, Tt, Tgd, Tgb		Upper Tertiary	TERTIARY
Tc, unconformity		Tlu			
Kk, unconformity	Tmb, Tma			Upper Cretaceous	CRETACEOUS
Kp, unconformity					
Kh, local unconformity				Lower Cretaceous	
Ka, Jn, unconformity	Jgd, Jgt, Jgr, Jgb			Upper Jurassic	JURASSIC
Jl, Trk				Lower Jurassic	
			Tc	Upper Triassic	TRIASSIC
			JPk	Lower Jurassic to Upper Permian	JURASSIC, TRIASSIC AND PERMIAN

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS AND SEDIMENTARY ROCKS

Qs **Surficial deposits (Holocene and Pleistocene)**--Unconsolidated to poorly consolidated alluvial, colluvial, glacial, lacustrine, marine, eolian, and eolian deposits. Locally includes extensive redeposited pumice and ash initially deposited during the 1912 Katmai eruption

Qls **Landslide deposits (Holocene and Pleistocene)**--Nonsorted, nonstratified coarse angular rubble forming hummocky masses

Ts **Sedimentary rocks (Tertiary)**--Poorly to moderately well indurated, fluvial sandstone, siltstone, and conglomerate; larger clasts consist of both plutonic and volcanic rocks of local derivation

Th **Hemlock Conglomerate (Oligocene)**--Poorly indurated fluvial conglomerate, pale brown tuffaceous sandstone, siltstone, shale, coal, and tuff. Age is late Oligocene

Tc **Copper Lake Formation (Tertiary)**--Massive, well indurated, polymictic conglomerate, sandstone, and siltstone. Age is early Tertiary

Kk **Kaguyak Formation (Late Cretaceous)**--Upper part consists of interbedded siltstone and graded greywacke sandstone that represent the upper and middle reliefs of a submarine fan. Lower part consists of thinly bedded siltstone and some thin limestone beds and includes abundant ammonites, pelecypods, and limestone concretions

Kp **Pedmar Formation (Early Cretaceous)**--Thick-bedded grey sandstone and minor amounts of siltstone and shale that contain ammonites of Albian age

Kh **Herendeen Formation (Early Cretaceous)**--Calcareous sandstone and siltstone, thinly bedded, lighter in color than Kk

Ka **Stanikovich Formation (Early Cretaceous)**--Siltstone, shale, and thinly bedded, fine-grained, feldspathic and laminoritic brown sandstone

Jn **Naknek Formation (Late Jurassic)**--Main sedimentary rock-unit of the map area, consisting of sandstone, conglomerate, siltstone, and dark shale. Divided into five members (not mapped here), from oldest to youngest: massive conglomerate and thinly bedded sandstone member; thick-bedded to massive sandstone member; thinly bedded, dark grey siltstone member with limestone concretions; thinly bedded sandstone and siltstone member; massive conglomerate member. Clasts in both the oldest and youngest conglomerate members are dominantly metamorphic, volcanic, and sedimentary rocks with subordinate plutonic rocks

Jt **Talkeetna Formation (Early Jurassic)**--Lava flows, breccias, and lahars locally interbedded with volcaniclastic sandstone, conglomerate, and shale. Includes sills of uncertain ages. Metamorphosed to non-schistose epidote-albite-actinolite assemblages suggestive of lower greenschist facies

Jk **Kamishak Formation (Late Triassic)**--Slightly to moderately recrystallized, non-fossiliferous limestone

VOLCANIC DEPOSITS AND ROCKS

Younger deposits and rocks of Aleutian volcanic arc

QHp **Pyroclastic-flow deposits (Holocene)**--Poorly sorted, variably indurated deposits of ash, vitrophyric blocks, and (or) pumiceous lapilli. Comprises the 1912 ash flow of Katmai (Hovergat) and the Holocene block-and-ash flows of Kaguyak caldera

Qhd **Domes (Holocene)**--Domes of dacitic or rhyolitic composition

Qpc **Younger central-vent deposits and rocks (Holocene and Pleistocene)**--Lava flows, tuffs, and breccias dominantly of andesitic composition but locally including lava flows of low-silica dacitic composition. Includes deposits of Trident Volcano, Mount Mageik, Mount Martin, Mount Mountain and Broken Mountain, and some of parasitic cones of Mount Katmai

QTap **Pyroclastic-flow deposits (Pleistocene and late Tertiary)**--Poorly sorted, variably indurated deposits of ash, vitrophyric blocks, and/or pumiceous lapilli. Primary compositions are uncertain owing to alteration but probably range from andesitic to dacitic

QTac **Older central-vent deposits and rocks (Pleistocene and late Tertiary)**--Lava flows, breccias, and domes of andesitic and dacitic composition. Locally moderate to extensive alteration associated with fossil fumaroles (e.g., bleaching to light red or yellow shades)

Tav **Older volcanic rocks of Aleutian volcanic arc (late Tertiary)**--Breccias, lava flows, tuffs, and local pyroclastic and epiclastic tuffs of late Tertiary volcanic field located southwest of the Aleutian Range crest and extending from the Katmai River to Bakun Bay. Dominantly of andesitic and dacitic composition. Propylitic alteration is extensive and argillic or potassic alteration is locally intensive, such as near contacts with hypabyssal intrusive rocks of unit Ti

Volcanic rocks of Meshik volcanic arc (Eocene)--Divided into:

Tmb **Basaltic lavas**--Flows, dikes, and flows of basaltic composition that intrude or overlie rocks of unit Tma

Tma **Andesitic and dacitic lava flows and breccia**--Unit also includes local domes or tuffs of rhyolite(?) composition, now altered to quartz and sericite or kaolinite

METAMORPHIC ROCKS

JPk **Kaskanak Complex (Jurassic, Triassic, and Permian)**--Locally foliated or banded quartzite, schist, amphibolite, and garnet-bearing gneiss indicative of amphibolite-facies metamorphism. Protoliths presumably consisted of Talkeetna Formation (Jt), Kamishak Formation (Jk), Cottonwood Bay Greenstone (Jc), and unnamed Permian(?) sandstone and argillite

Jc **Cottonwood Bay Greenstone (Late Triassic)**--Basalt flows now metamorphosed to epidote-albite-actinolite assemblages suggestive of greenschist facies; also locally includes chert and fine- to medium-grained diabase

INTRUSIVE ROCKS

d **Dikes (Tertiary)**--Dikes from 1 m to 20 m wide that occur southeast of the Bruin Bay fault, that is, in rocks no older than the Naknek Formation (Jn). Many are in rocks as young as the Hemlock Conglomerate (Th); however, suggesting that most are middle to late Tertiary in age

Tt **Hypabyssal intrusive rocks of Aleutian volcanic arc (late Tertiary)**--Silli-tike or cross-cutting subvolcanic intrusive bodies generally less than 10 sq km in outcrop area, as well as larger plutonic bodies such as those beneath Fourpeaked volcano or along the Aleutian Range crest east of Serpent Tongue Glacier. Fine-grained, porphyritic to equigranular rocks that consist dominantly of granodiorite or tonalite and minor quartz diorite

Tlu **Hypabyssal intrusive rocks (Tertiary)**--Intrusive bodies ranging from small plugs and sills to plutons exposed over as much as 30 sq km. Rocks are fine- to medium-grained, commonly porphyritic, and consist chiefly of quartz diorite or tonalite

Tgd **Granodiorite (Tertiary)**--Medium-grained equigranular to marginally porphyritic rocks that are low in modal quartz; unit includes samples that are classified as quartz monzodiorites

Tgb **Quartz diorite (Tertiary)**--Medium-grained equigranular rocks in which most of modal quartz ranges widely, rocks of the unit include tonalite and monzonite

Tgb **Gabbro and diorite (Tertiary)**--Medium-grained rocks having gabbroic or diabasic textures

Jgr **Granite (Jurassic)**--Medium-grained equigranular or fine-grained porphyritic rocks

Jgd **Granodiorite (Jurassic)**--Medium-grained equigranular or fine-grained porphyritic rocks. Also includes isolated outcrops of tonalite and quartz diorite

Jqd **Quartz diorite and tonalite (Jurassic)**--Medium-grained equigranular rocks

Jgb **Diorite and gabbro (Jurassic)**--Dark, diabasic- and gabbroic-textured rocks

GEOLOGIC MAP SYMBOLS

Contact--Dashed where inferred or approximately located, dotted where concealed; queried where uncertain. Dropthrown side, D-downthrown side

Thrust or reverse fault--Sawteeth on upper plate; bar with number indicates dip of fault plane

Anticlinal axis--Showing direction of plunge; dashed where approximately located; dotted where concealed; queried where existence uncertain

Synclinal axis--Showing direction of plunge; dashed where approximately located; dotted where concealed; queried where existence uncertain

Measured strike and dip of beds

Approximate strike and dip of beds

Inferred strike of foliation

Horizontal bedding

Dike

Quaternary volcanic vent

Area of alteration

STUDIES RELATED TO AMRAP

The U.S. Geological Survey is required, by the Alaskan National Interests Lands Conservation Act (ANILCA, Public Law 96-487), to survey certain federal lands to determine their mineral values(1) and, mineral resources(2) and to assess the environmental effects(3) that may result from mineral development that is allowable to the public and be submitted to the President and the Congress. This report presents the results of a geochemical survey of the Mount Katmai quadrangle, and parts of the Afognak and Naknek quadrangles, Alaska.

INTRODUCTION

During the summers of 1983-85, we conducted a reconnaissance geochemical and mineralogical survey of the Mount Katmai quadrangle and parts of the Afognak, Naknek, and Iliamna quadrangles, Alaska. The study area comprises approximately 10,000 km² (2,400 mi²) in the Shelikof Strait area of the Alaska Peninsula between 153° and 157° longitude and 58° and 59° latitude. The study area encompasses all of the Katmai National Park and Preserve, as well as a part of the McNeil State Game Preserve.

The topographic relief in the study area is 7,090 ft (2,170 m), with a maximum altitude at the summit of Snowy Mountain. The terrain in the central and eastern parts of the Katmai study area is rugged and mountainous and contains youthful stream drainages in previously glaciated valleys. The western part of the Katmai study area, west of the Bruin Bay fault, is part of the Mount Katmai eruption of 1912 (Fenner, 1920), has been deeply incised and was not sampled. The western part of the Katmai study area is a low tundra plain covered by a deep mantle of glacial, lacustrine, and eolian deposits. There are no outcrops of bedrock exposed. Large glacial lakes preserved in the area were formed behind terminal moraines after the retreat of the glaciers (Kellar and Reiser, 1999).

Sampling was confined largely to the alpine and foothills terrains in the eastern and central parts of the Katmai study area. Two different media were sampled: (1) stream sediments, and (2) panned concentrates of heavy-mineral fractions from stream sediments. The fine-grained (<0.177 mm-80-mesh sieve-fraction) material was chosen because geology and geochemistry, and also reveals areas of extensive epoxene mineralization, whereas the nonmagnetic heavy-mineral-concentrate medium will concentrate the ore-related minerals present and may be useful in delineating areas of poorly exposed mineralization.

This report, one of a series of reports that graphically present selected geochemical and mineralogical data in map format, presents geochemical results from emission spectrographic analysis of nonmagnetic heavy-mineral-concentrate samples; MF-2021-A (Church, and others, 1989) presents the geochemical results from emission spectrographic analysis of minus-80-mesh stream-sediment samples; MF-2021-B (Church, and Meloche, 1989) presents the results of inductively coupled plasma analysis of leachable metals from the minus-80-mesh stream-sediment samples; MF-2021-D (Church and Bennett, 1989) presents mineralogical data from binocular microscopic examination of nonmagnetic heavy-mineral-concentrate samples. An interpretive report, which delineates selected areas of mineralization within the Katmai study area and interprets the significance of the geochemical and mineralogical signatures of these anomalous areas, is in preparation.

GEOLOGY

Geologic mapping of the Mount Katmai region includes early reconnaissance work by Keller and Reiser (1959) and preliminary results of the AMRAP study (Riehle and others, 1987). Stratigraphic relations of sedimentary units throughout the entire Alaska Peninsula are consistent with recent revisions (R.A. Detterman, written commun., 1989).

The Katmai study area includes part of the Alaska Peninsula magmatic arc. Intrusive rocks range in age from Eocene to Holocene (oldest or slightly younger Jurassic plutons (Jgr, Jgd, and Jgb) as well as by Cretaceous and Tertiary plutons (Tgd, Tgb, and Tgb), comprise the Alaska-Aleutian Ranges batholith that extends from the southern margin of the study area north to the vicinity of Mount Denali (Formerly, Mount McKinley) (Reed and Lanphere, 1969; 1973). Some of the Cretaceous intrusive rocks found elsewhere in the batholith have been identified despite 38 radiometric age determinations on rocks from the study area (M.A. Lanphere and F.H. Wilson, written commun., 1988). Roof pendants are a heterogeneous assemblage of schist, gneiss, quartzite, marble, and amphibolite (Jpzc, Jpzm, and Jpzq) some of which include Jurassic volcanic rocks (Jtk), Jurassic basalt flows and limestone (Rk and Kk), and possibly older sedimentary and (or) volcanic rocks.

Extrusive rocks (Tmb, Tma) of middle Tertiary age (F.H. Wilson, written commun., 1987) are part of the Meshik volcanic arc, which extends from the southern Kenai Peninsula southwestward for 1,500 km along the crest of the Aleutian Range (Wilson, 1985). Tertiary plutons of the Alaska-Aleutian Ranges batholith (Tgd, Tgb, and Tgb), in the Iliamna quadrangle, be the deep-seated equivalents of the Meshik volcanic rocks. Centers of Miocene volcanism (Tav), located immediately seaward of the currently active Quaternary vents (Qap, Qpc, and Qad), document the onset of the modern Aleutian arc. Volcanic rocks (Tav, Tlu, and Tt) of the Katmai volcanic field, which are younger than the Meshik volcanic rocks, may be intermediate in age between the older and younger parts of the arc. Shallow intrusions of late Tertiary (Tt) and Tertiary (Tlu) age have locally been metamorphosed and (or) hydrothermally altered the Tertiary volcanic rocks east of the range crest as well as the Mesozoic sedimentary rocks west of the range crest.

The most extensive rock unit in the region is the Naknek Formation (Jn), a composite of Upper Jurassic shallow marine, fluvial, and fluvial fluvial conglomerates, sandstones, and siltstones that document the unroofing and erosion of the Jurassic arc (Detterman, 1986). Jurassic rocks are preserved in the Naknek area and Talkeetna Mountains, siltstone, and calcareous sandstone (Kk, Kp, Kk, and Kh) and Tertiary conglomerate, sandstone, and siltstone, locally tuffaceous and (or) volcanic rocks (Ts, Th, and Tc). The main structural feature of the study area is the Bruin Bay fault, a high-angle reverse fault 480 km in length (Detterman and Hartsock, 1966; Detterman and others, 1976) that, in the Katmai study area, juxtaposes the batholith and older rocks on the west against the Naknek Formation on the east. Other structural features include north- to northeast-trending folds and northwest-trending, high-angle normal faults, fractures, veins, and dikes; most or all of such features in the study area are probably late Tertiary in age.

SAMPLE COLLECTION, PREPARATION, AND ANALYSIS

We collected heavy-mineral-concentrate samples from active alluvium in the high-energy portion of the stream. Sample sites were primarily from 1st-order (headwater) streams and second-order (Strahler, 1964) streams. Samples were collected from a depth of 10 cm to 30 cm in unconsolidated alluvium, using a 10-mesh (2.0-mm) screen to remove the coarse material. The heavy-mineral-concentrate fraction was panned from most of the drainage basins sampled range from 2 m³ (5 m³) to about 10 m³ (20 m³). Each bulk sample was screened with a 10-mesh (2.0-mm) screen to remove the coarse material. The heavy-mineral-concentrate fraction was panned from most of the quartz, feldspar, organic material, and clay-sized material were removed. After air drying in the field, the samples were sent to the laboratory for heavy-mineral separation. The samples were sieved to minus-30-mesh (0.6 mm) and the remaining quartz and feldspar was separated from the heavy-mineral-concentrate fraction, using bromoform (specific gravity about 2.9). The heavy-mineral-concentrate fraction was further separated into three fractions, using a large electromagnet (Ballary and others, 1986). The most-magnetic, first-fraction material, primarily magnetite, and a second fraction, largely ferromagnesian silicates and iron oxides, were not analyzed. The third fraction (the least-magnetic material, which may include the nonmagnetic ore minerals, zircon, sphene, and so forth) was examined to determine the mineralogy of the sample and then split, using a Jones splitter. One split was hand-ground for spectrographic analysis; the other split was archived for future work. We reported mineralogical results from 961 sites (Bennett and others, 1989). Because semiquantitative emission spectrographic methods (Grimes and Marranzino, 1968) for the nonmagnetic heavy-mineral-concentrate samples are given in Bailey and others (1986; table 3, p. 70-126). Duplicate samples were taken at 62 sites. An analysis of variance for data from these sites was not practical because of the large number of censored distributions in the data set.

A statistical summary of the geochemical data from the 1038 nonmagnetic heavy-mineral-concentrate samples is given in table 1. Because semiquantitative spectrographic data are reported in geometrically spaced classes (Grimes and Marranzino, 1968; Sinclair, 1974), the data are in fact discontinuously variable data. Furthermore, several of the distributions are censored by the lower limit of determination. Cohen's method of estimating the geometric mean and geometric deviation has been used to estimate these parameters for censored distributions with detection ratios greater than about 0.5 (Cohen, 1959). The skewness and kurtosis of these censored distributions were estimated after replacing qualified values with one-half of the lower determination limit of the element if qualified with an L, with one-quarter of the lower determination limit if qualified with an N, and with a value one class interval larger than the lower determination limit if qualified with a G. The skewness and kurtosis values for both the raw data and the log-transformed data are given in table 1. Rock and Ahrens (1985) and Rock (1988) use the 5 percent confidence limits (Bennett and Franklin, 1954, p. 95) to estimate whether a particular trace-element distribution more closely approximates a log-normal rather than a normal population. All of the data except for titanium have distributions that are more nearly log-normal than arithmetic-normal. Selected percentiles of the data are also given in table 1.

The eight elements for which data are shown on map A of this report are the same group of elements shown on the stream-sediment geochemical map (MF-2021-A, Church and others, 1989). A second suite of generally less abundant elements, selected to reflect sulfide mineralization expected in this geologic environment, are shown on map B. Histograms of these data are shown in figures 1 and 2. Elements that show strong geochemical coherence, for example molybdenum (Mo) and tungsten (W), or trace metals that would readily substitute for major rock-forming elements, for example nickel (Ni) and cobalt (Ag) for lead (Pb), are shown on the corresponding vector on map B. The anomalous element concentrations are shown by vectors that radiate from sample localities indicated by small circles. The vectors are subdivided into three lengths that approximate the 90th, 95th, and 98th percentile distributions of the data (see the histograms of the data, figs. 1 and 2). Antimony (Sb) is designated by the chemical symbol on map B when detected. Threshold values selected for the entire study area were very similar to those chosen by Golofard and others (1988), for the area underlain by tertiary volcanic rocks (Tav) in the southwest part of the Katmai quadrangle.

The lithologic and geochemical and mineralogical diversity of the heavy-mineral suite, the data sets for all of the elements plotted are censored. Boron has a mode at 50-100 ppm that probably represents marine shales. Likewise, barium has a mode at 500-1000 ppm that also represents a marine sedimentary environment. Nickel has a mode at 50-100 ppm that represents large accumulations of zircon, probably reflecting drainages having high percentages of conglomerate in the drainage basin. For the majority of the elements, only the large positive tail of the distribution was plotted. The results for zinc, copper, and lead show the presence of anomalous concentrations of these elements, but can also be used to indicate the lithologic and (or) mineralogic controls on distribution. Zinc values are indicated by patterns in the Naknek and Tertiary sedimentary rocks and samples characteristic of particular mineral deposit types.

Clusters of similar data on the geochemical maps may represent a deposit that have large areal exposure. Clusters of base- and precious-metal anomalies are widespread south and southwest of the Cape Douglas area. Vein mineralization is indicated by the anomalies along the southern part of the Katmai study area underlain by Tertiary volcanic rocks (Tav). Porphyry mineralization is indicated in the Mount Griggs area, Mount Kejulik, and the Mount Douglas area. Skarn mineralization is indicated in the Mount Katolinat area. Additional porphyry and skarn mineralization, with associated precious metal veins, is indicated in the northwest part of the Katmai quadrangle. These anomalies are associated with the Tertiary intrusive rocks (Tgd, Tgd, Tgb) of the Alaska-Aleutian Range batholith. Some isolated anomalies (Mo, W, Ag, and Au) occur in the Meshik volcanic rocks (Tmb, Tma) and may indicate concealed mineralization.

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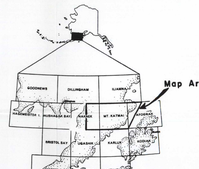

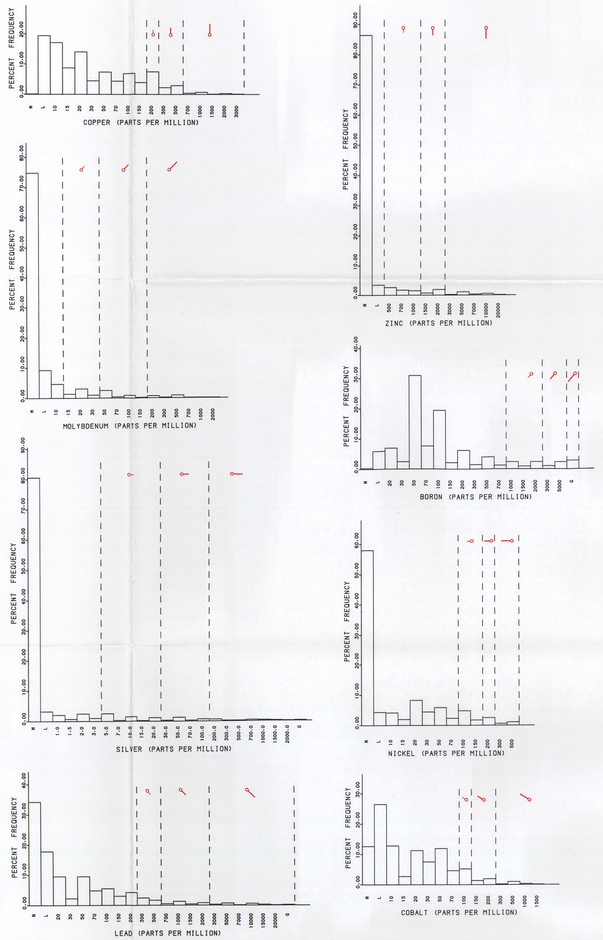

Figure 1. Histograms showing the distribution of values determined for the eight elements shown on map A. The length of the vectors shown on each histogram indicates the concentrations of each element plotted on map A.

TABLE 1.--Statistical summary of the geochemical data from the nonmagnetic heavy-mineral concentrates from the Mount Katmai and parts of the Afognak and Naknek quadrangles, Alaska

[Method of analysis: Semiquantitative emission spectrographic values reported in ppm except for Mg, Ca, Fe, and Ti, which are reported in percent. Geometric mean expressed as the log of the concentration. Leaders (--) indicate insufficient or no data; > = greater than]

Element	Data based on the qualified population: DR[1]	N[2]	L[3]	G[4]	No of values	Minimum	Median	90th	95th	98th	Maximum	Geometric Mean	Geometric Deviation	Expected Mean[5]	Skewness[6]	Kurtosis[6]
	Data based on the qualified population					Minimum	Median	Percentiles				Data based on the log transformed population				
Mg	0.983	0	18	0	1,020	0.05	0.30	2.0	3.0	5.0	10.0	0.39	3.21	0.04-6.02	0.224	-0.459
Ca	1.000	0	0	0	1,038	.10	2.0	5.0	7.0	10.0	20.0	0.38	3.01	-.99-5.68	.403	1.19
Fe	1.000	0	0	0	1,038	.10	2.0	5.0	7.0	10.0	20.0	0.38	3.01	-.99-5.68	.648	.157
Ti	.673	0	0	339	699	.02	1.5	>2.0	>2.0	>2.0	5.0	1.47	3.53	.12-18.3	(.054)	(-1.50)
B	.940	3	61	0	945	20	70	1,000	5,000	>5,000	5,000	101	3.50	8.6-1,290	1.06	.842
Ba	.014	549	474	0	15	2.0	20	500	--	--	--	--	--	--	--	--
Be	.564	296	156	0	585	200	2,000	5,000	5,000	10,000	10,000	224	3.46	19-2,682	.743	-.045
Sr	.056	38	91	0	129	50	500	10,000	>10,000	>10,000	>10,000	839	4.77	70-10,044	.271	-.066
Bi	.995	383	0	0	525	50	200	300	500	2,000	41	3.75	5.57	-.832	-.322	
Cr	.999	0	1	0	1,037	200	1,000	1,000	2,000	2,000	2,000	293	2.86	29-2,265	.11	-.781
Zr	.132	0	0	901	137	20	>2,000	>2,000	>2,000	>2,000	2,000	--	--	--	--	--
Mn	.054	861	137	0	50	20	500	1,000	1,000	5,000	100	--	--	--	--	--
Th	.013	1,005	15	0	18	200	200N	200N	200N	<200	500	--	--	--	--	--
Sc	.855	73	77	0	888	10	30	70	100	100	200	27	2.56	4.177	-.375	-.641
Mo	1.000	0	0	0	1,038	50	500	1,000	2,000	2,000	5,000	111	3.46	140-2,510	-.273	-.537
Y	.992	0	13	0	1,026	20	150	300	500	500	1,000	72	2.16	24-527	.361	.481
La	.971	32	30	0	1,036	50	200	200	150	700	300	38	3.34	3-312	-.734	-.397
W	.377	602	45	0	391	10	10N	100	150	200	500	--	--	--	--	--
Cu	.609	131	275	0	632	10	70	100	200	300	1,000	13	4.49	-1.262	.889	-.195
Pb	.478	538	0	0	836	20	70	150	300	1,000	7,000	15	4.63	-1.530	.802	.120
Zn	.160	776	96	0	166	10	10N	20	50	200	2,000	--	--	--	--	--
Ag	.478	355	185	0	496	20	<20	200	700	3,000	20,000	15	10.36	.1-1,610	1.70	3.05
Bi	.041	990	5	0	43	20	20N	20N	20N	70	1,000	--	--	--	--	--
Cd	.018	1,000	0	0	18	167	1N	167	1N	1N	1,000	--	--	--	--	--
Au	.048	972	3	0	50	20	20N	20N	30	500	500	--	--	--	--	--
Sb	.000	1,038	0	0	0	500	500N	500N	1,000	3,000	20,000	--	--	--	--	--
Cd	.025	997	20	0	26	50	50N	50N	50	500	2,000	--	--	--	--	--
As	.061	956	19	0	63	500	500N	500N	500	1,500	20,000	--	--	--	--	--
Sn	.001	1,036	1	0	1	500	200N	200N	200N	200N	500	--	--	--	--	--
W	.048	966	22	0	50	100	100N	100N	<100	700	5,000	--	--	--	--	--
Sn	.120	36	902	0	136	10	50	50	50	50	1,500	--	--	--	--	--

[1]Detection Ratio (DR) is the number of uncensored values (that is those without N, L, and G) divided by the total number of samples analyzed.

[2]N is the number of qualified observations could not be estimated but lower detection limit.

[3]L is the number of samples in which the element was observed, but the concentration was less than the lower determination limit.

[4]G is the number of samples in which the element was observed, but the concentration was greater than the upper determination limit.

[5]The 95.percent expected range (Miesch, 1976) is calculated from the geometric mean (GM) and geometric deviation (GD) as follows: $(GM)(GD^{1.96})$ to $(GM)(GD^{-1.96})$ where the limits are rounded to two significant digits.

[6]The arithmetic distribution for Ti is more normal than the log-transformed distribution; values of skewness and kurtosis shown in parentheses.

GEOCHEMICAL MAPS SHOWING THE DISTRIBUTION OF SELECTED ELEMENTS DETERMINED IN HEAVY-MINERAL CONCENTRATES FROM THE MOUNT KATMAI AND PARTS OF THE AFOGNAK AND NAKNEK QUADRANGLES, ALASKA

By
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