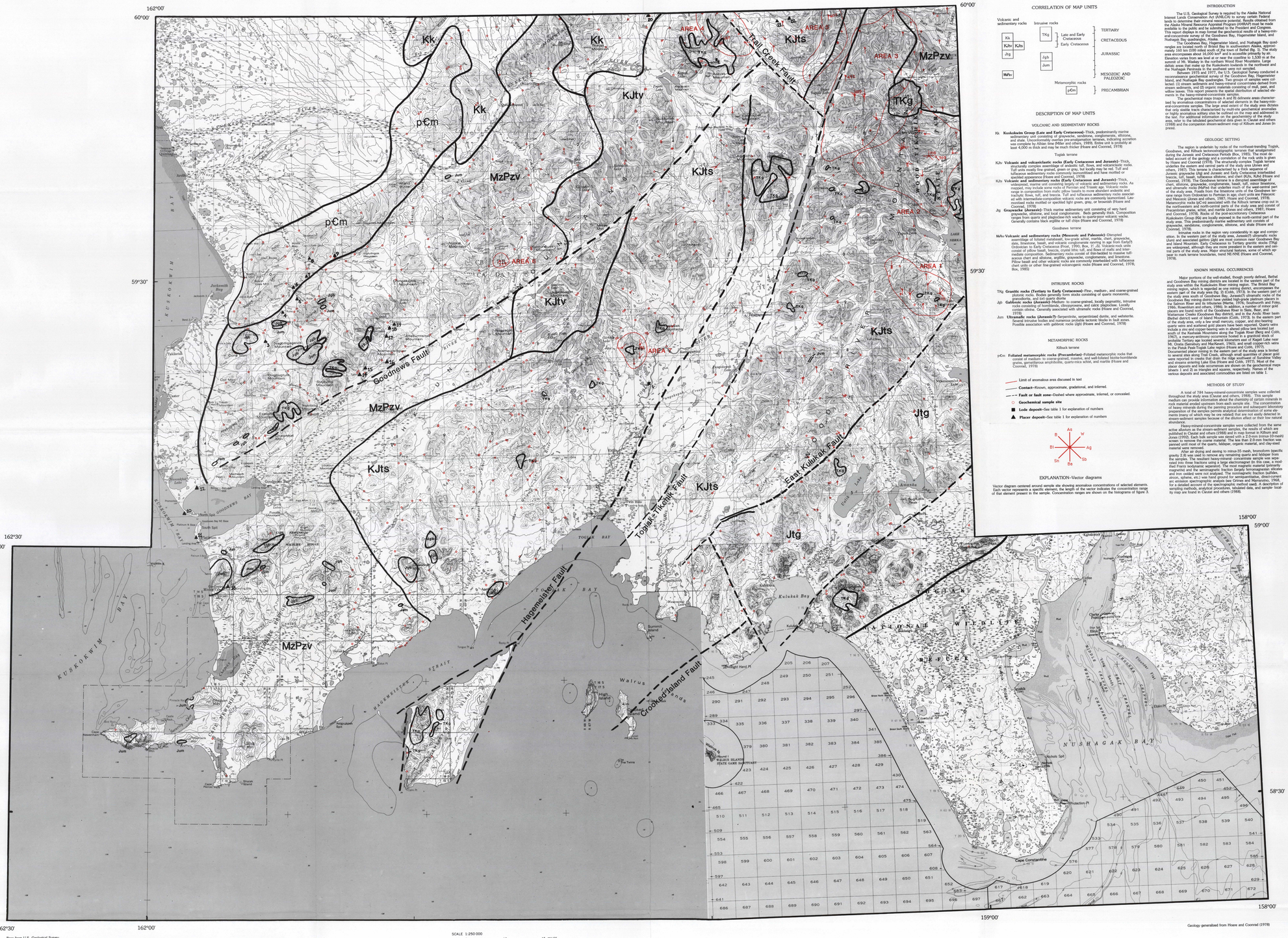


Base from U.S. Geological Survey Goodnews Bay, 1979; Hagemeister Island, 1957; and Nushagak Bay, 1952

SCALE 1:250 000

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100-FOOT INTERVALS
DATUM IS MEAN SEA LEVEL

CORRELATION OF MAP UNITS

DESCRIPTION OF MAP UNITS

VOLCANIC AND SEDIMENTARY ROCKS

Ks **Kuskokwim Group (Late and Early Cretaceous)**—Thick, predominantly marine sedimentary unit consisting of graywacke, sandstone, conglomerate, siltstone, and shale. Unconformably overlies pre-amalgamation terranes, indicating accretion was complete by Albian time (Box and others, 1985). Unit is at least approximately at least 4,000 m thick and may be much thicker (Hoare and Coonrad, 1978)

Togiak terrane

KJfs **Volcanic and volcaniclastic rocks (Early Cretaceous and Jurassic)**—Thick, structurally complex assemblage of mafic tuff, flows, and volcaniclastic rocks. Tuff units mostly fine grained, green or gray, but locally may be red. Tuff and tuffaceous sedimentary rocks commonly thoroughly recrystallized and have mottled or speckled appearance (Hoare and Coonrad, 1978)

KJtv **Volcanic and volcaniclastic rocks (Early Cretaceous and Jurassic)**—Thick, surficial, reverse and consisting largely of volcanic and sedimentary rocks. As mapped, may include some rocks of Permian and Triassic age. Volcanic rocks range in composition from mafic pillow basalts to more abundant andesitic and trachytic flows, tuff, and breccia. Tuff and tuffaceous sedimentary rocks associate with flows and volcaniclastic rocks. Sedimentary rocks consist of conglomerate, sandstone, and minor rocks overlaid or spotted light green, gray, or brownish (Hoare and Coonrad, 1978)

Jtg **Graywacke (Jurassic)**—Thick marine sedimentary unit consisting of very hard graywacke, siltstone, and local conglomerate. Beds generally thick. Composition ranges from quartz and plagioclase-rich wacke to quartz-poor volcanic wacke. Generally contains black argillite or tuff clasts (Hoare and Coonrad, 1978)

Goodnews terrane

MzPzv **Volcanic and sedimentary rocks (Mesozoic and Paleozoic)**—Disrupted assemblage of foliated metabasalt, low-grade schist, marble, chert, graywacke, argillite, siltstone, tuff, and volcanic conglomerate ranging in age from Early(?) Ordovician to Early Cretaceous (Box, 1990; Box, 1', 2). Volcanic rock units consist of pillow basalt, breccia, crystal lithic tuff, and flows of mafic and intermediate composition. Sedimentary rocks consist conglomerate, siltstone, acceous chert and siltstone, argillite, graywacke, conglomerate, and limestone. Rocks of Paleozoic age are locally recrystallized and commonly interbedded with tuffaceous chert rocks or other fine-grained volcanogenic rocks (Hoare and Coonrad, 1978; Box, 1985)

INTRUSIVE ROCKS

TKg **Granitic rocks (Tertiary to Early Cretaceous)**—Fine-, medium-, and coarse-grained plutonic rocks. Bodies generally form stocks consisting of quartz monzonite, granodiorite, and granite (Box, 1985)

Jgb **Gabbroic rocks (Jurassic)**—Medium- to coarse-grained, locally porphyritic, intrusive rocks consisting of hornblende, clinopyroxene, and calcic plagioclase. Locally contain olivine. Generally associated with ultramafic rocks (Hoare and Coonrad, 1978)

Jum **Ultramafic rocks (Jurassic?)**—Serpentinite, serpentinized dunite, and wehlerite. Several intrusive bodies and numerous probable tectonic blocks in fault zones. Possible association with gabbroic rocks Ugb) (Hoare and Coonrad, 1978)

METAMORPHIC ROCKS

Kilbuck terrane

p€m **Foliated metamorphic rocks (Precambrian)**—Foliated metamorphic rocks that consist of medium- to coarse-grained, massive, and well-foliated biotite-hornblende gneiss, garnetiferous amphibolite, quartz-mica schist, and marble (Hoare and Coonrad, 1978)

Limit of anomalous area discussed in text

Contact—Known, approximate, gradational, and inferred.

Fault or fault zone—Dashed where approximate, inferred, or concealed.

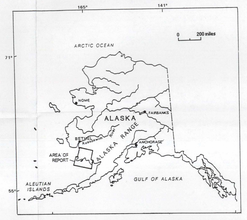
Geochemical sample site

Lode deposit—See table 1 for explanation of numbers

Placer deposit—See table 1 for explanation of numbers

EXPLANATION—Vector diagrams

Vector diagram centered around sample site showing anomalous concentrations of selected elements. Each vector represents a specific element, the length of the vector indicates the concentration range of that element present in the sample. Concentration ranges are shown on the histograms of figure 3.



Geology generalized from Hoare and Coonrad (1978)

Table 1. Known mineral occurrences
[Data from Martin, 1976]

Number on map	Name	Commodity
	Lode deposits	
1	Togiak River	copper, zinc
2	Kagati Lake	antimony, mercury
	Placer deposits	
3	Jacksmith Creek	gold
4	Domingo Creek	gold
5	Platinum Creek	gold, platinum
6	Butte Creek	gold, platinum
7	Fox Creek	gold
8	Snow Gulch	gold, platinum
9	Tyrone Creek	gold
10-11	Goodnews Bay	chromium, gold
12	Goodnews Bay	chromium
13	Goodnews Bay	platinum
14	Slate Creek-Weltamuse Creek	gold
15	Ophir Creek	gold
16	Fox Gulch	gold
17-18	Bear Creek	gold
19	Canyon Creek	gold
20	Ratny Creek	gold
21-22	Trail creek	gold

Table 2. Statistical summary of heavy-mineral concentrate data, Goodnews, Hagemeister Island, and Nushagak Bay Quadrangles, Alaska
[Values reported in ppm, except for Mg, Fe, Ca, and Ti, which are in percent; (-), no data. Detection ratio (DR) is number of samples in which element was detected by total number of samples analyzed for a single element. N, elemental concentrations not detected at lower determination limit. G, elemental concentrations above upper limit of determination. Geometric mean calculated after setting all values with N equal to 1/4 of lower determination limit and setting values with equal to twice upper determination limit]

ELEMENT	D/R	GEOMETRIC MEAN	MIN	MEDIAN	90th	95th	98th	MAX
Ag	0.02	-	N	N	N	N	1	20
As	0.03	-	N	N	N	500	1,500	G10,000
B	0.91	102	20	70	1,000	2,000	G2,000	G2,000
Ba	0.92	498	N	300	5,000	G5,000	G5,000	G5,000
Be	0.37	1	N	N	5	5	7	G200
Bi	0.01	-	N	N	N	N	G2,000	G200
Ca	0.91	14	N	20	50	G20	G20	G20
Co	0.95	23	N	20	50	100	150	300
Cr	0.96	207	N	700	3,000	5,000	G5,000	G5,000
Cu	0.96	42	N	30	300	500	1,000	5,000
Fe	0.85	11	0.7	10	G20	G20	G20	G20
La	0.52	43	N	50	200	300	700	G1,000
Mg	0.96	4	0.2	5	10	10	G10	G10
Mn	0.86	2,620	200	2,000	G5,000	G5,000	G5,000	G5,000
Mo	0.03	-	N	N	N	N	20	200
Nb	0.05	-	N	N	N	N	70	200
Ni	0.96	71	N	70	200	300	300	700
Pb	0.35	-	N	N	70	100	200	7,000
Sb	0.01	-	N	N	N	N	N	700
Sc	0.76	86	N	70	G100	G100	G100	G100
Sn	0.02	-	N	N	N	N	50	G2,000
Sr	0.81	129	N	200	500	700	700	3,000
Ti	0.54	1	0.1	1	G1	G1	G1	G1
V	1.00	448	150	500	700	700	700	2,000
W	0.04	-	N	N	200	300	500	2,000
Y	1.00	87	20	70	200	300	500	1,000
Zn	0.02	-	N	N	N	500	700	3,000
Zr	0.72	495	70	500	G1,000	G1,000	G1,000	G1,000

INTRODUCTION

The U.S. Geological Survey is required by the Alaska National Interest Lands Conservation Act (ANILCA, P.L. 96-487, Section 1010) to assess the mineral resource potential. Results obtained from tasks to determine their mineral resource potential (MRAP) must be made available to the public and be submitted to the President and Congress. This report displays in map format the geochemical results of a heavy-mineral-concentrate survey of the Goodnews Bay, Hagemeister Island, and Nushagak Bay quadrangles, Alaska.

The Goodnews Bay, Hagemeister Island, and Nushagak Bay quadrangles are located north of Bristol Bay in southwestern Alaska, approximately 160 km (100 miles) south of the town of Bethel (fig. 1). The study area encompasses about 16,000 km² and is accessible primarily by air. Elevation varies from sea level at or near the coastline to 1,530 m at the top of Mt. Waskey. Most of the study area is underlain by sedimentary and volcanic rocks that make up the Kuskokwim lowlands in the northwest and the Nushagak Peninsula in the southeast were not sampled.

Between 1975 and 1977, the U.S. Geological Survey conducted a reconnaissance geochemical survey of the Goodnews Bay, Hagemeister Island, and Nushagak Bay quadrangles. Samples were collected and analyzed: (1) stream sediments and heavy-mineral concentrates derived from stream sediments, and (2) organic materials consisting of moss, peat, and willow leaves. This report presents the spatial distribution of selected elements in the heavy-mineral-concentrate samples.

Results from this survey have delineated 9 discrete areas characterized by anomalous concentrations of selected elements in the heavy-mineral-concentrate samples. The large areal extent of the study area dictates that only visible tracts characterized by multi-site geochemical anomalies or highly anomalous solitary sites be outlined on the map and addressed in the text. For additional information on the geochemical data in these areas, refer to the tabulated geochemical data given in Causlat and others (1988) and the comparator stream-sediment map of Kilburn and Jones (in press).

GEOLOGIC SETTING

The region is underlain by rocks of the northeast-trending Togiak, Goodnews, and Kilbuck tectonostratigraphic terranes that amalgamated during the Jurassic and Cretaceous Periods (Box, 1985). The most detailed account of the geology and a correlation of the rock units is given in Hoare and Coonrad (1978). The Togiak terrane is the largest terrane underlies the eastern and central parts of the study area (Jones and others, 1987). This terrane is characterized by a thick sequence of Jurassic graywacke (Jtg) and Jurassic and Early Cretaceous interbedded breccia, tuff, basalt, tuffaceous siltstone, and chert (KJfs; Kjtv) (Hoare and Coonrad, 1978). The Goodnews terrane is a structurally complex belt of chert, siliceous graywacke, conglomerate, basalt, tuff, minor limestone, and ultramafic rocks (MzPzv) that underlies much of the west-central part of the study area. Fossils from the limestone units of the Goodnews terrane range from Ordovician to Permian in age; chert units are Paleozoic and Mesozoic (Box, 1985; Box, 1', 2; Box and others, 1985). The Kilbuck terrane rocks (p€m) associated with the Kilbuck terrane crop out in the northwestern and north-central parts of the study area and consist of Precambrian gneiss, schist, and marble (Jones and others, 1987; Hoare and Coonrad, 1978). Rocks of the post-accretionary Cretaceous Kuskokwim Group (Ks) are locally exposed in the north-central part of the study area. This predominantly marine sedimentary unit consists of graywacke, siltstone, conglomerate, siltstone, and shale (Hoare and Coonrad, 1978).

Intrusive rocks in the region vary considerably in age and composition. In the western part of the study area, Jurassic(?) ultramafic rocks (Jum) and associated gabbro (Jgb) are most common near Goodnews Bay. Tertiary granitic rocks (TKg) and associated hornfels and skarn deposits are widespread, although they are more prevalent in the eastern and central parts of the study area. Major structural features, some of which appear to mark terrane boundaries, trend NE-NNE (Hoare and Coonrad, 1978).

KNOWN MINERAL OCCURRENCES

Major portions of the well-studied, though poorly defined, Bethel and Goodnews Bay mining districts are located in the northwest part of the study area within the Kuskokwim River mining region. The Bristol Bay mining region, which is the largest in Alaska by area, encompasses the eastern part of the study area (fig. 2) (Cobb, 1973). In the western part of the study area south of Goodnews Bay, Jurassic(?) ultramafic rocks of the Goodnews Bay district have yielded placer platinum and chromite from the Salmon River and its tributaries (Martin, 1916). Southwards and East, placer gold has been found in the Platinum, Fox, Snow, a number of minor gold placers are found north of the Goodnews River in Slate, Bear, and Weltamuse Creeks (Goodnews Bay district), and in the Arctic River basin (Bethel district west of Island Mountain (Cobb, 1973). In the eastern part of the study area, only a few small mercury, copper, and zinc occurrences are known in association with Tertiary granitic rocks. These veins include a zinc and copper-bearing vein in altered pillow lava located just south of the Kashavik Mountains along the Togiak River (Berg and Cobb, 1967), a mercury-antimony occurrence hosted in a granitic stock of probable Tertiary age located several kilometers east of Kagati Lake near the head of Togiak Bay (Cobb, 1973), and a gold-quartz-scheelite vein in the Portage Peak-Togiak Lake region (Hoare and Cobb, 1977). Documented placer mining in the eastern part of the study area is limited to several sites along Trail Creek, although small quantities of placer gold were reported in creeks that drain the ridge southwest of Sunshine Valley (Hoare and Coonrad, 1978; Jones and others, 1987). Lode and placer deposits and lode occurrences are shown on the geochemical maps (sheets 1 and 2) as triangles and squares, respectively. Names of the various deposits and associated commodities are listed on table 1.

METHODS OF STUDY

A total of 784 heavy-mineral-concentrate samples were collected throughout the study area (Causlat and others, 1988). This sample medium can provide information about the chemistry of certain minerals in rock material eroded upstream from each sample site. The concentration of heavy minerals in the samples is increased by panning and laboratory preparation of the samples permits analytical determination of some elements (many of which may be one related) that are not easily detected in stream-sediment samples because of the dilution effect or their low natural abundance.

The heavy-mineral-concentrate samples were collected from the same active alluvium as the stream-sediment samples, the results of which are published in Causlat and others (1988) and in map format in Kilburn and Jones (1992). Each bulk sample was sieved with a 2.0-mm (minus-10-mesh) screen to remove the coarse material. The less than 2.0-mm fraction was panned to remove the quartz, feldspar, organic material, and clay-sized material were removed.

After air drying and sieving to minus-35 mesh, bromoform (specific gravity 2.8) was used to remove any remaining quartz and feldspar from the samples. The resultant heavy-mineral- concentrate sample was separated into a magnetic and a nonmagnetic fraction using a hand-held Frantz isodynamic separator. The most magnetic material (primarily magnetite) and the semimagnetic fraction (largely ferromagnesian silicates and iron oxides) were not analyzed. The nonmagnetic fraction (sulfides, zircon, sphene, etc.) was hand ground for semiquantitative, direct-current arc emission spectrographic analysis. Dean and others (1981) provide an overall account of the spectrographic method used. A description of sampling methods, analytical procedures, tabulated data, and sample- locality map are found in Causlat and others (1988).

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Figure 1. Index map of Alaska, showing location of Goodnews Bay, Hagemeister Island, and Nushagak Bay quadrangles, Alaska.

A statistical summary of the heavy-mineral-concentrate geochemical data is given in table 2. Histograms for the elements of economic or shading silver, arsenic, boron, barium, bismuth, cobalt, chromium, copper, gallium, lead, mercury, molybdenum, antimony, tin, tungsten, and zinc, are shown on sheets 1 and 2. Histograms of these data are displayed on figure 3. These elements were chosen because it was thought that they best represent the pathfinder elements for mineral deposits in this area. Histograms for the elements silver, arsenic, bismuth, molybdenum, antimony, tin, and tungsten are shown on a logarithmic scale, as compared with cautious because of the highly concealed nature of the data.

Anomalous-element concentrations for both the histograms and the map are depicted as vectors that radiate from a central point. These vectors are subdivided into three lengths based on anomalous concentrations of selected elements. The longest vector represents anomalies. 3) and related percentiles (table 2). In the case of the map, the central circle (o) represents the sample-site localities and is the central point of the vector symbol.

GEOCHEMICAL ANOMALIES

Inspection of the geochemical maps (maps A and B) reveals a number of areas of multi-element anomalies, many of which were previously unknown, or at least undocumented. These areas have been numbered 1 through 7 on the maps. These divisions do not represent specific mineral occurrences, but rather delineate the geographic extent of the heavy-mineral-concentrate anomalies.

Gold was detected in any of the heavy-mineral- concentrate samples and is, therefore, not presented on either map. This is particularly surprising since gold placers are known to exist in the study area and anomalous concentrations of gold were detected in stream-sediment samples collected from the study area (Causlat and others, 1988). Much of the gold, if it may present, may be relatively fine-grained and is lost during panning.

The most highly anomalous regions are located in the northeastern part of the study area. They include the regions located near Sunshine Valley (area 1), Rainbow Basin (area 2), the convergence of the Trail Creek and Goodnews Faults (area 3), and the area near the High Lake (area 5). The Sunshine Valley region (area 1) is defined by the presence of multi-element anomalies of arsenic, barium, lead, tungsten, zinc, and (less consistently) antimony. Twenty-five percent of the arsenic concentrations detected in samples collected from this region were greater than 1,000 ppm, and arsenic values as high as 10,000 ppm (Sample 478. Sample 478 also contains high concentrations of lead (104 ppm), bismuth (20 ppm), tungsten (500 ppm), and antimony (200 ppm). Gold (≥0.05 ppm) and an anomalous concentration of arsenic (1,500 ppm) were additionally found in the stream-sediment sample collected at this site (Kilburn and Jones, 1992).

Heavy-mineral concentrates collected in Rainbow Basin (area 2) contain multi-element anomalies of arsenic, silver, boron, bismuth, cobalt, copper, lead, tin, zinc and (less consistently) barium, molybdenum, and antimony. Arsenic concentrations ranging from 700 ppm to more than 10,000 ppm are widespread throughout the area. Silver (≥2 ppm), tin (≥ 100 ppm) were anomalous in about half of the samples collected from area 2. The most anomalous concentrations of antimony in 2 samples (sites 705 and 703, both at the lower detection limit of 200 ppm) is significant. Antimony anomalies may indicate the presence of epithermal mercury-antimony occurrences such as those at Kagati Lake (Sainsbury and MacKevett, 1965) were commonly associated with concentrations of >10,000 ppm arsenic, >1,000 ppm bismuth, 300 ppm cobalt, 50 ppm tin, and 200 ppm antimony. Anomalous gold (0.05 ppm) and arsenic (2,000 ppm) concentrations also were found in the associated stream-sediment sample collected at this site (Kilburn and Jones, 1992).

Areas 1 and 3 are defined by anomalies produced by volcanic and volcaniclastic rocks of the Togiak terrane (Box, 1985). Tertiary felsic intrusions and associated hornfels zones are common in these areas (Hoare and Coonrad, 1978) and are spatially related to the geochemical anomalies. Martin (1916), Cobb (1973), and Hoare and Coonrad (1978) discussed the probability of lode-gold deposits in this part of the Goodnews Bay quadrangle and suggested that the gold is associated with hornfels, sedimentary rocks and associated granitic rocks in the Rainbow Basin-Sunshine Valley region. The anomalies in areas 1 and 2 may reflect occurrences similar to the so called "red spots" discussed by Frost (1990) in the Bethel quadrangle to the north. "Red Spots" are areas of oxidized pyrite-bearing rhyolite dikes and associated sulfide-bearing quartz veins. Mineralization is gold-base metal-quartz systems hosted in volcanic, volcaniclastic, and sedimentary rocks of the Togiak and Tikchik terranes in the southeastern part of the Bethel quadrangle. The dike/vein systems bear an anomalous trace element signature (silver, arsenic, gold, copper, mercury, molybdenum, lead, antimony, and tungsten) similar to that associated with the heavy-mineral-concentrate samples collected in areas 1 and 2.

Area 3 yielded heavy-mineral concentrates containing anomalous concentrations of arsenic, boron, barium, cobalt, and copper. This anomalous tract is located west of a large felsic intrusive body and intruded into rocks of the Togiak terrane (Box, 1985). Tertiary felsic intrusives and volcaniclastic rocks of the Togiak terrane (Box, 1985). Heavy-mineral-concentrate sample 692 contained >5,000 barium, 200 ppm cobalt, and 1,500 ppm copper, with 1 ppm Hg in the corresponding stream-sediment sample (Kilburn and Jones, 1992). A sample of argillite collected from an outcropping of a quartz-pyrite-stockwork yielded 0.05 (1.5 ppm) and molybdenum (20 ppm) (Coonrad and others, 1978).

The Mt. Oratia region (area 4) is located about 3 km north-northeast of the Kagati Lake mercury-antimony deposit where mineralized veins are enclosed in a quartz monzonite and granodiorite stock of probable Tertiary age. One mineralized vein yielded a mercury-antimony-bearing sample (Sainsbury and MacKevett, 1965). Heavy-mineral concentrate samples collected from area 4 contain anomalous concentrations of arsenic, copper, lead, tin, and less consistently silver, antimony, and zinc. The area is underlain primarily by Cretaceous volcanic and sedimentary rocks (Box, 1985; Box and others, 1978) of the Togiak terrane (Box, 1985). Stream sediments in the area yielded anomalous concentrations of arsenic, lead, at sites 685 and 687 gold was also detected (0.15 ppm and <0.05 ppm, respectively) (Kilburn and Jones, 1993). Anomalous base-metal concentrations in samples collected from area 4 contrast with the Kagati Lake deposit which is notably base metal poor. Most likely, the base-metal anomalies in area 4 are unrelated to any of the Kagati Lake mercury-antimony-bearing mineralization.

High Lake (area 5), which is underlain by volcanic and volcaniclastic rocks of the Togiak terrane (Box, 1985), is characterized by anomalous concentrations of copper, lead, zinc and less consistently, barium and cobalt in the heavy-mineral concentrates. Sample 502, collected in the northwestern part of the lake, yielded 1,500 ppm copper and anomalous concentrations of 1,000 ppm copper, 300 ppm lead, and 1,000 ppm zinc. The geochemical anomalies contained in area 5 roughly coincide with a small unnamed fault that parallels the Togiak-Tikchik fault.

Area 6, located in the central part of the study area, is underlain by mafic rocks of the Goodnews terrane (Box, 1985; Box and others, 1985; Hoare and Coonrad, 1978; Box, 1985). The area is defined by a single sample (277) containing 7 ppm silver, 5,000 ppm copper, 7,000 ppm lead, and 1,500 ppm zinc. The sample locality is spatially associated with a small, unnamed northeast-trending fault. However, no other anomalous heavy-mineral-concentrate samples were collected in the vicinity of this fault.

Heavy-mineral concentrates collected from area 7, located several kilometers southwest of the Kashiak Mountains, contain anomalous concentrations of arsenic, tungsten and, less consistently, bismuth, copper, molybdenum, and lead. Sample 292 contains >10,000 ppm arsenic, 500 ppm tungsten, 1,500 ppm copper, 300 ppm lead, and 1,000 ppm molybdenum. Tertiary granitic stock and associated hornfels zone mark the core of the anomalous area (Hoare and Coonrad, 1978). Stream-sediment samples collected from the immediate vicinity are anomalous in arsenic, copper, molybdenum, lead, and zinc. Heavy-mineral samples collected from a stream-sediment sample collected from a 1992). Sulfide and lodi oxide-bearing hornfels samples collected from a small, unnamed northeast-trending fault. However, no other anomalous heavy-mineral-concentrate samples were collected in the vicinity of this fault.

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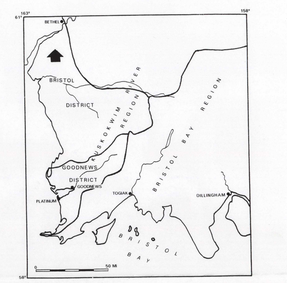

Figure 2. Map showing approximate location of mining regions and districts in Goodnews Bay, Hagemeister Island, and Nushagak Bay quadrangles, Alaska.

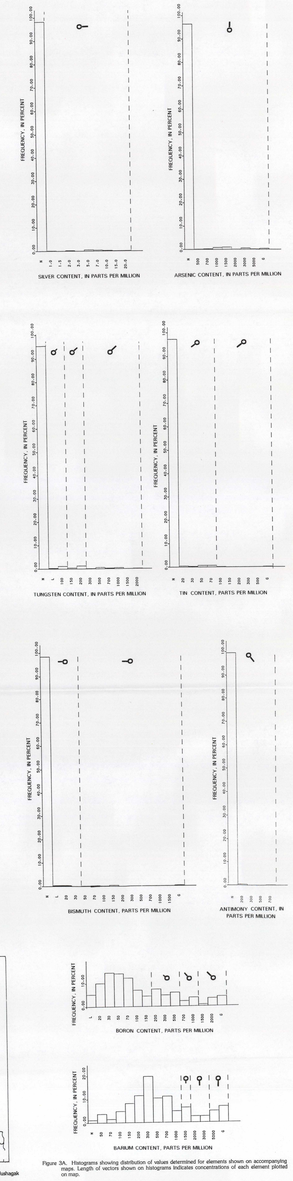

Figure 3A. Histograms showing distribution of values determined for elements shown on accompanying maps. Length of vectors shown on histograms indicates concentrations of each element plotted on map.

Map A. Map showing concentration-range vector diagrams (for Ag, As, B, Ba, Bi, Sb, Sn, and W) centered on geochemical-sample sites

GEOCHEMICAL MAPS SHOWING THE DISTRIBUTION OF SELECTED ELEMENTS DETERMINED IN HEAVY-MINERAL-CONCENTRATE SAMPLES FROM THE GOODNEWS BAY, HAGEMEISTER ISLAND, AND NUSHAGAK BAY QUADRANGLES, ALASKA

By

Janet L. Jones and James E. Kilburn

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