U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-2355
SHEET 2 OF 2

## STUDIES RELATED TO ALASKA MINERAL RESOURCE APPRAISAL PROGRAM (AMRAP)

The U.S. Geological Survey is required by the Alaska National Interest Lands Conservation Act (ANILCA) to survey certain Federal lands to determine their mineral resource potential. Results from the Alaska Mineral Resource Appraisal Program (AMRAP) 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 stream-sediment survey of the Goodnews Bay, Hagemeister Island, and Nushagak Bay quadrangles, Alaska.

## INTRODUCTION

Between 1975 and 1977, the U.S. Geological Survey conducted a reconnaissance geochemical survey in the Goodnews Bay, Hagemeister Island, and Nushagak Bay quadrangles, Alaska. Two dissimilar groups of samples were collected: (1) stream sediments and heavy-mineral concentrates derived from stream sediments, and (2) organic materials consisting of mull, peat, and willow leaves. This report presents the spatial distribution of selected anomalous elements determined in stream-sediment samples. A separate report by Jones and Kilburn (1992) presents similar information for the heavy-mineral-concentrate samples.

The study area, which lies between the lower Nushagak and Kuskokwim River basins, is marked by mountainous terrain and isolated ridges separated by broad, flat, generally glaciated valleys. Although much of the region is covered by waters of the Bering Sea and unconsolidated surficial deposits, three distinct physiographic provinces are recognized. These include an alpine province consisting of the rugged Wood River and Ahklun Mountains, a piedmont province characterized by low-rolling hills, and a coastal province containing large deltaic or foreland areas of little or no topographic relief (Mertie, 1976). The region is drained by several large rivers and numerous streams that flow westward into Kuskokwim Bay or eastward and southward into Bristol Bay. A few small glaciers are found in some of the higher alpine valleys, remnants of a once large ice field that covered much of the study area.

The geochemical map delineates areas characterized by anomalous concentrations of selected elements in stream-sediment samples. Because of the large areal extent of the study area, only sizable tracts characterized by prominent geochemical signatures or highly anomalous solitary sites are outlined on the map and addressed in the text. For additional information on the geochemistry of the study area, the reader is referred to the tabulated geochemical data given in Cieutat and others (1988) and the companion heavy-mineral-concentrate maps of Jones and Kilburn (1992).

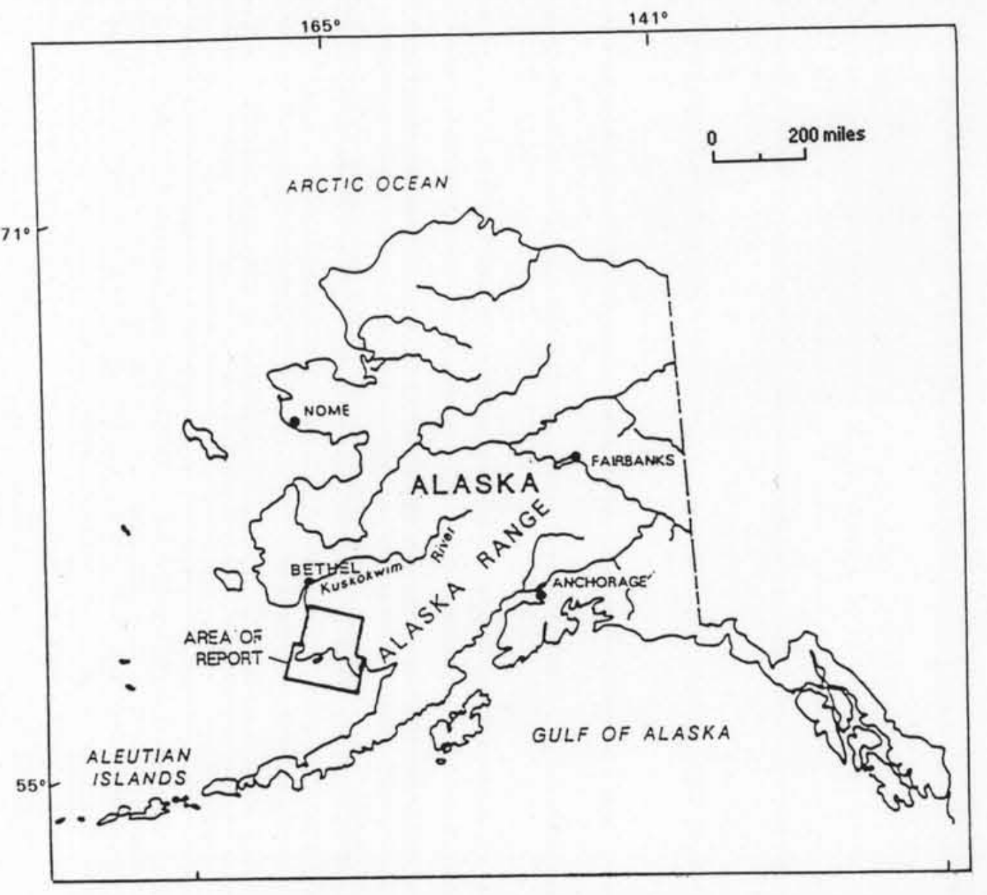

Figure 1. Index map of Alaska, showing location of the Goodnews Bay, Hagemeister Island, and Nushagak Bay quadrangles, Alaska.

## GEOLOGIC SETTING

The region is underlain by rocks of the northeast-trending Togiak, Goodnews, and Kilbuck tectono-stratigraphic terranes that amalgamated in the Jurassic and Cretaceous Periods (Box, 1985). The most detailed account of the geology and a correlation of the rock units can be found in Hoare and Coonrad (1978). The structurally complex Togiak 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 (KJts, KJtv) (Hoare and Coonrad, 1978). The Goodnews terrane is a disrupted assemblage of chert, siltstone, graywacke, conglomerate, basalt, tuff, minor limestone, and ultramafic rocks (MzPzv) that underlie 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 (Jones and others, 1987; Hoare and Coonrad, 1978). Metamorphic rocks of the Kilbuck terrane (pЄm) crop out in the northwest and west-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 (Kk) are locally exposed in the north-central part of the study area. These predominantly marine sedimentary rocks consist of graywacke, sandstone, conglomerate, siltstone, and shale (Hoare and Coonrad, 1978).

Intrusive rocks in the region range considerably in age and composition. Jurassic(?) ultramafic rocks (Jum) and associated gabbros (Jgb) are most common in the west near Goodnews Bay and Island Mountain. Early Cretaceous to early Tertiary granitic stocks (TKg) are widespread, although more prevalent in the central and eastern parts of the study area. Major structural features, some of which appear to mark terrane boundaries, trend northeast to northnortheast (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 western part of the study area within the Kuskokwim River mining region. The Bristol Bay mining region, which is regarded as one mining district, 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 mining district have yielded high-grade platinum placers in the Salmon River and its tributaries (Mertie, 1976; Southworth and Foley, 1986; Rosenblum and others, 1986). In addition, a number of minor gold placers are found north of the Goodnews River in Slate, Bear, and Wattamuse Creeks (Goodnews Bay district), and in the Arolic 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-bearing quartz veins and scattered gold placers have been reported. Quartz veins include the following: a zinc-and copper-bearing vein in altered pillow lava just south of the Kashaiak Mountains along the Togiak River (Berg and Cobb, 1967); a mercury-antimony occurrence hosted in a granitoid stock of Late Cretaceous age located several kilometers east of Kagati Lake, near Mt. Oratia (Sainsbury and MacKevett, 1965); and small copper-rich veins in the Pistuk 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 and streams entering Lake Elva (Hoare and Cobb, 1977). Most of the placer deposits and lode occurrences are shown on the geochemical map as triangles and squares, respectively. Names of the various deposits and associated commodities are listed in table 1.

**Table 1. Known mineral occurrences**
[Data from Cobb and Condon, 1972; Mertie, 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 | Kowkow 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-<br>Wattamuse Creek | Gold |
| 15 | Olympic Creek | Gold |
| 16 | Fox Gulch | Gold |
| 17-18 | Bear Creek | Gold |
| 19 | Canyon Creek | Gold |
| 20 | Rainy Creek | Gold |
| 21-22 | Trail Creek | Gold |

## METHODS

A total of 777 stream-sediment samples were collected from drainages in the study area. Samples consisted of alluvium gathered primarily from first- or second-order active stream drainages, as shown on U.S. Geological Survey 1:63,500-scale topographic maps. The stream-sediment samples were air dried, sieved to minus-80-mesh, and pulverized to produce a homogeneous sample for analysis. Stream-sediment samples are considered to be a representative composite of bedrock and colluvium exposed in the confines of the drainage basin, upstream from the sample site. Chemical analysis of stream sediments can reveal changes in bedrock geology and geochemistry and may also be indicative of mineralized areas upstream. Samples were analyzed using the semiquantitative emission spectrographic method described by Grimes and Marranzino (1968) and Motooka and Grimes (1976). Stream-sediment samples were also analyzed by more sensitive and precise techniques, for specific elements of interest; copper, lead, and zinc, by the atomic absorption method of Ward and others (1969); gold, by the atomic absorption method of Thompson and others (1968); and mercury, by a modified method of McNerney and others (1972) and Vaughn and McCarthy (1964). A description of the sampling methods and analytical procedures employed are found in Cieutat and others (1988).

A statistical summary of the stream-sediment geochemical data set is shown in table 2. No data are reported in table 2 for the elements bismuth, cadmium, tin, and tungsten because there were no valid determinations. The distribution of anomalous values for 8 ore and ore-related elements are shown on the geochemical map. Histograms of these data are displayed in figure 3. Anomalous element concentrations for both the histograms and map are represented as vectors that radiate from a central point. On the map, the circle indicates the sample site locality. These vectors are subdivided into one, two, or three lengths based on anomalous concentrations determined by subjective review of the elemental histograms (fig. 3) and related percentiles (table 2).

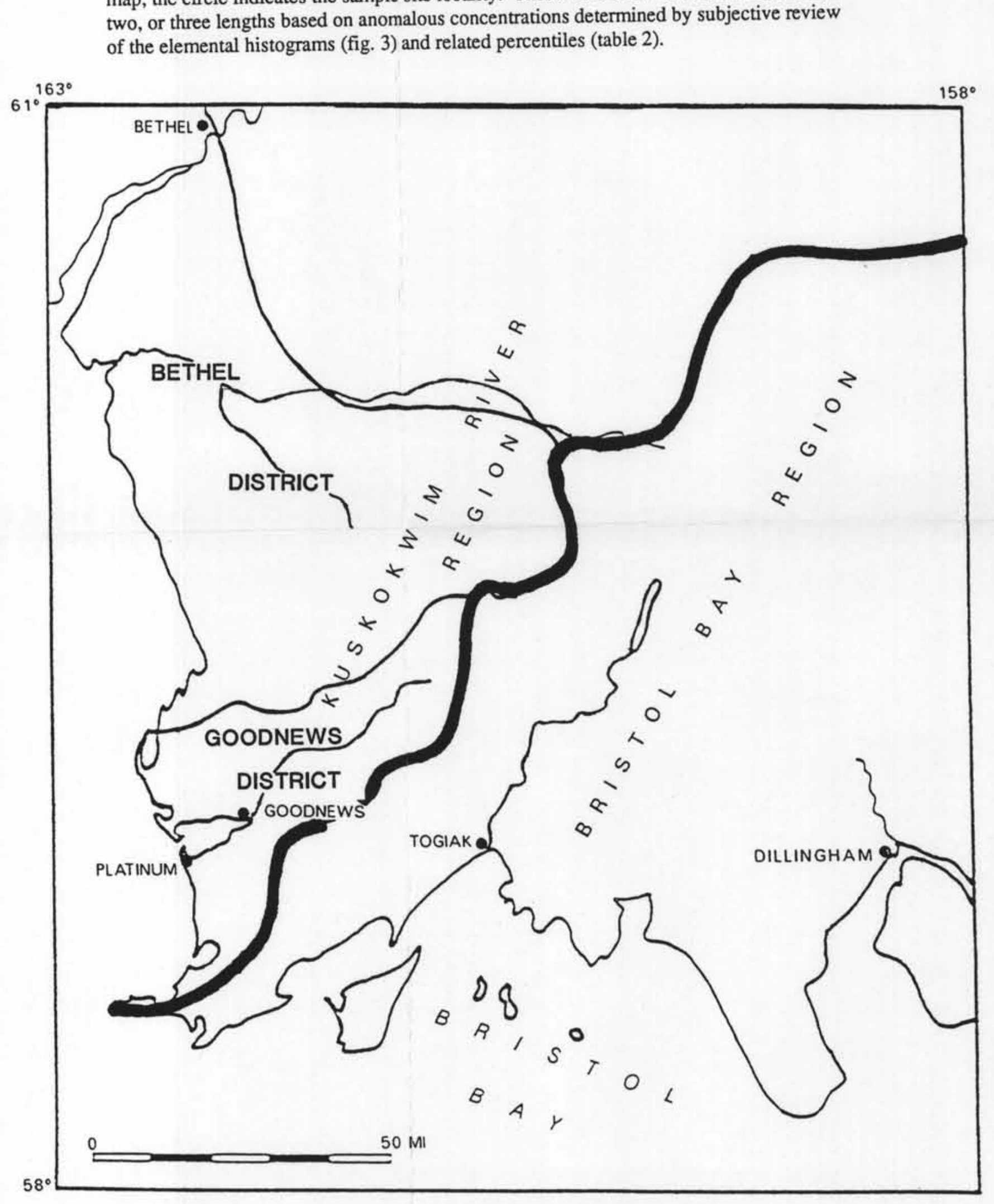

Figure 2. Map showing approximate location of mining regions and districts in the Goodnews Bay, Hagemeister Island, and Nushagak Bay quadrangles, southwest Alaska.

**Table 2. Statistical summary of stream-sediment data from Goodnews Bay, Hagemeister Island, and Nushagak Bay quadrangles, Alaska**

[The detection ratio (DR) is the number of uncensored values divided by the total number of samples analyzed for a given element. N, elemental concentrations that could not be detected at the lower determination limit; L, elemental concentrations that were reported as observable but are less than the lower determination limit; G, elemental concentrations that are above the upper level of determination. Analysis of all elements except Hg by semiquantitative emission spectrography. Au, Cu, Pb, and Zn also analyzed by atomic absorption (AA). Combustion released Hg determined by atomic absorption or resistivity.]

| Element | DR | Geometric Mean[1] | Minimum | Median | 90th | 95th | 98th | Maximum |
|---|---|---|---|---|---|---|---|---|
| Silver | 0.01 | -- | N | N | N | N | N | 1 |
| Arsenic | .02 | -- | N | N | N | N | N | 2000 |
| Gold (AA) | .04 | -- | N | N | N | N | .15 | 7 |
| Barium | 1.00 | 636 | 100 | 700 | 700 | 1000 | 1000 | 1000 |
| Beryllium | .98 | 2 | N | 2 | 2 | 2 | 3 | 10 |
| Cobalt | 1.00 | 26 | N | 30 | 30 | 50 | 50 | 100 |
| Chromium | 1.00 | 111 | L15 | 100 | 300 | 500 | 700 | 2000 |
| Copper | 1.00 | 60 | 7 | 70 | 100 | 100 | 100 | 200 |
| Copper(AA) | 1.00 | 45 | 5 | 45 | 90 | 110 | 160 | 260 |
| Iron | 1.00 | 6 | .7 | 7 | 10 | 10 | 15 | 15 |
| Mercury | .99 | .10 | N | .1 | .24 | .34 | .70 | 2 |
| Magnesium | 1.00 | 2 | .15 | 1.5 | 2 | 3 | 3 | 5 |
| Manganese | 1.00 | 1555 | 300 | 1500 | 2000 | 3000 | 3000 | G10,000 |
| Molybdenum | .06 | -- | N | N | N | 5 | 10 | 20 |
| Nickel | 1.00 | 51 | L5 | 50 | 70 | 100 | 150 | 700 |
| Lead (AA) | 1.00 | 17 | 5 | 20 | 25 | 30 | 30 | 360 |
| Lead | .98 | 21 | N | 20 | 50 | 50 | 50 | 70 |
| Antimony | .01 | -- | N | N | N | N | N | 150 |
| Titanium | .94 | .63 | .15 | .7 | 1 | G1 | G1 | G1 |
| Zinc | .28 | 113 | N | N | 200 | 300 | 500 | 1000 |
| Zinc (AA) | 1.00 | 101 | 10 | 100 | 160 | 190 | 220 | 560 |

[1] Geometric mean was calculated after setting all values with N equal to one-fourth of the lower determination limit, all values with L equal to one-half the lower determination limit, and values with G equal to twice the upper determination limit. Leader (--) indicates detection ratio too low to give meaningful geometric mean.

## GEOCHEMICAL ANOMALIES

Areas 1-7, outlined on the geochemical map, are characterized by prominent elemental anomalies (large vector, fig. 3). These areas do not necessarily contain mineralized tracts or deposit types; they are geochemically favorable for the presence of certain metallic mineral resources.

### Area 1

Gold and chromium anomalies were identified in stream-sediment samples collected around Island, Twin, and Sugtutlig Mountains, near the western margins of the study area. These metals were detected primarily in creeks and tributaries of the Arolic and Goodnews Rivers. In addition, less consistent lead and arsenic anomalies occur in Area 1. The Arolic and Goodnews River basins contain former placer gold-producing sectors of the Bethel and Goodnews Bay mining districts, respectively (Cobb, 1973). No other mining activity or mineral occurrences are known in or around Area 1. No associated anomalies were detected in the corresponding concentrate samples from Area 1 (Jones and Kilburn, 1992). This may be explained in part by the sample preparation procedure, which can preferentially remove certain ore and ore-related minerals such as chromite, magnetite, and fine gold from the concentrate.

Area 1 is underlain by a lithologically distinct segment of the Goodnews terrane that is described as a matrix-poor melange of Early(?) Ordovician to Early Cretaceous marine volcanic and sedimentary rocks (Box, 1985; Jones and others, 1987). Locally abundant plutonic rock units range from Jurassic mafic and Jurassic(?) ultramafic bodies, to Late Cretaceous to early Tertiary granitoid stocks (Hoare and Coonrad, 1978). Quaternary glacial deposits cover much of the lowland country, including the broad gravel-filled valleys of the Goodnews and Arolic basins, where known gold placers are located.

Four stream-sediment samples, collected in creeks that drain both flanks of the divide separating the Goodnews and Arolic River basins between Kisogle Mountain and Sugtutlig Mountains, contain 0.05-2 ppm gold. The samples were gathered in the immediate proximity of extensively worked late Pleistocene to post-Pleistocene gold placers of the Goodnews Bay district. The placer deposits, which were probably formed by the reconcentration of older alluvium (Hoare and Coonrad, 1961), were originally staked on Bear Creek in 1916, with claims staked soon thereafter on highly productive Wattamuse Creek (Hoare and Cobb, 1977). There is little doubt that the gold anomalies are simply chemical manifestations of these documented placers. The initial source of the gold, however, is problematic. According to Cobb (1973), the gold is probably derived from auriferous quartz veins in contact zones surrounding several granitic stocks in the divide above the placers. A hornfelsed rock sample collected from the ridge above Wattamuse Creek was anomalous in arsenic (500 ppm) and tin (20 ppm); an amphibolite from the same general area contained 0.2 ppm gold and 3,800 ppm copper (Coonrad and others, 1978).

The remainder of the anomalous gold (five sites ranging from 0.1 ppm to 4.5 ppm Au) is in stream-sediment samples composited from creeks draining the known gold-bearing Arolic River basin (Bethel Mining district); gold placers in this area were first discovered in the early 1900's and are presumed to be of pre-Pleistocene age (Hoare and Coonrad, 1961). West of Island Mountain in Butte Creek, Snow Gulch, and Kowkow Creek, gold was mined and small amounts of platinum were recovered (Hoare and Cobb, 1977). Although discernable gold in the sediment samples probably comes from known placer occurrences, the bedrock source of the gold, like that in the Goodnews basin, is conjectural. Cobb (1973) suggests that a good deal of the gold may be derived from contact aureoles enclosing nearby felsic intrusive stocks. The Snow Gulch placers, on the other hand, are spatially removed from felsic intrusive bodies and may be associated with mineralization along a northeast-trending fault that extends the entire length of the drainage in Precambrian metamorphic rocks (Hoare and Cobb, 1977). Similarly, the gold anomaly located on the north side of Twin Mountain occurs near a fault zone in Jurassic gabbros, some distance from mapped granitic units.

The chromium anomalies are mainly concentrated near Island Mountain and probably indicate the presence of chromite-bearing mafic and ultramafic rocks in this part of the study area. The ultramafic assemblage at Island Mountain consists of Jurassic(?) serpentinite, serpentinized dunite, and websterite bodies that are frequently associated with mafic gabbros of Jurassic age (Hoare and Coonrad, 1978). The small quantities of platinum that are found locally in gold placers may be derived from these same ultramafic rocks (Cobb 1973). Platinum is closely associated with chromite and magnetite in the dunite core of the Jurassic Goodnews Bay ultramafic unit of Southworth and Foley (1986), 50 km (31 mi) to the south.

The origin of the anomalous lead (35-360 ppm) and arsenic (200-300 ppm) is uncertain; both are geochemically incompatible with mafic and ultramafic rocks. Most of these anomalies are found downstream from granitic rocks in the Explorer Mountain region and may be related.

### Areas 2 and 3

Two distinct areas, in and adjacent to the Togiak-Tikchik and Hagemeister fault zones, are delineated by anomalous copper values. The first includes a number of tracts in the Pistuk Peak-Togiak Lake region (Area 2) and the second is a small but highly anomalous area in the vicinity of the Kashiak Mountains (Area 3). Both areas are coincident with Jurassic and Early Cretaceous volcanic and volcaniclastic rocks of the Togiak terrane. Late Cretaceous to early Tertiary granitic stocks locally intrude the volcanic and sedimentary units (Hoare and Coonrad, 1978) and are spatially associated with the copper anomalies.

The copper anomalies (ranging from 160 ppm to 220 ppm) in the Pistuk Peak-Togiak Lake region (Area 2) outline a rather large expanse situated on both sides of a major north-trending fault zone. Anomalous stream-sediment samples generally lack other associated elemental anomalies and no corresponding heavy-mineral-concentrate samples are anomalous. East of Togiak Lake, however, two widely separated heavy-mineral-concentrate samples contain anomalous ore-related elements. One is anomalous in copper, molybdenum, and zinc and the other in bismuth, molybdenum, and tungsten (Jones and Kilburn, 1992). East of Togiak Lake, gold (0.6 ppm) was also detected in one stream-sediment sample. The relationship of these geochemical anomalies to the copper anomalies, other than geographic, is unknown. Rock samples (mostly tuffs) on the other hand, are sporadically anomalous in copper (as much as 460 ppm) and zinc (as much as 200 ppm) throughout Area 2 (Coonrad and others, 1978). Area 2, which is centered on a Late Cretaceous to early Tertiary felsic stock, contains more than 76 percent of the study areas stream-sediment copper anomalies (long vectors on fig. 3) as well as several documented copper mineral occurrences. Hoare and Cobb (1977) describe these occurrences as (1) chalcopyrite and malachite in a small quartz vein in the centrally placed granitoid stock, near the contact with hornfelsed sedimentary rocks; and (2) traces of copper minerals in a large north-trending fault zone hosted in fine-grained tuff and tuffaceous sedimentary rocks. It is possible that the copper anomalies may indicate other similar copper occurrences in Area 2.

Area 3, located several kilometers southwest of the Kashaiak Mountains, is anomalous in copper (as much as 260 ppm), arsenic (as much as 1,500 ppm), zinc (260 ppm), molybdenum (20 ppm), and lead (35 ppm). Heavy-mineral-concentrates in the immediate area are collectively anomalous in arsenic, molybdenum, copper, bismuth, and tungsten (Jones and Kilburn, 1992). The surrounding bedrock geology is comparable to that of the Pistuk Peak-Togiak Lake area (Area 2), including the presence of several granitic intrusive bodies (Hoare and Coonrad, 1978). Area 3 is located a few kilometers north of the Togiak River copper-zinc lode occurrence, a quartz vein 30-38 cm (12-15 in.) thick, exposed for 8 m (25 ft) in altered pillow lava. About 30 percent of the vein consists of nearly black, coarsely crystalline sphalerite with minor amounts of pyrite and chalcopyrite (Berg and Cobb, 1967). Sulfide and (or) oxide-bearing hornfels samples collected from a ridge near the southeast corner of Area 3 contained anomalous concentrations of as much as 100 ppm tungsten, 10 ppm molybdenum, and 180 ppm copper (Coonrad and others, 1978).

### Areas 4 through 6

A total of 14 anomalous mercury sample sites are displayed as long vectors (fig. 2) on the geochemical map. Most of these are spatially associated with faults, or granitic intrusions and related hornfels zones. Outlined on the geochemical map are three areas with anomalous mercury concentrations of note. These include two small areas in the northeast part of the study area (Areas 4 and 5) and a larger, linear tract east of the Togiak-Tikchik fault in the southeast part of the study area (Area 6). The underlying geology is essentially the same for all three areas, consisting primarily of Jurassic and Early Cretaceous volcanic and volcaniclastic rocks of the Togiak terrane.

Epithermal mercury-antimony deposits are comparatively common throughout southwest Alaska, particularly in the Kuskokwim and Nushagak River basins (Sainsbury and MacKevett, 1965). Much of the study area lies between these prominent drainage systems, and the presence of significant mercury anomalies is not surprising. Cinnabar and stibnite are the principle ore minerals in these regional epithermal mercury-antimony deposits; realgar, orpiment, native mercury, pyrite, limonite, and hematite are also locally present (Sainsbury and MacKevett, 1965). The mercury-antimony deposits occur mainly in quartz-carbonate veins and stockworks in and adjacent to competent graywacke and carbonate rocks, mafic dikes, and rhyolite or monzonite bodies. Veins are typically localized where bedding plane faults in the surrounding sedimentary rocks crosscut these more competent units (Sainsbury and Mackevett, 1960).

Areas 4-6 are characterized by a virtual absence of other elemental anomalies, including antimony and arsenic, common pathfinders for epithermal mercury deposits (Boyle, 1974). However, arsenic and antimony in stream-sediment samples were determined by emission spectrography, which lacks the required sensitivity to adequately detect minor or trace amounts of these elements (the lower limits of determination are 100 ppm and 200 ppm for antimony and arsenic, respectively). Recent studies by Gray and others (1991) indicate that concentrations greater than approximately 1 ppm antimony, 10 ppm arsenic, and 1 ppm mercury in minus-80-mesh stream-sediment samples are indicative of upstream mercury-antimony mineralization in the Kuskokwim River region.

Area 4 is located approximately 6 km (4 mi) east of Kagati Lake. The area contains two diverse anomalies almost 8 km (5 mi) apart, one of mercury and the other a molybdenum-enriched drainage associated with gold, arsenic, and copper. The mercury anomaly is delineated by a single stream-sediment sample (0.65 ppm Hg) collected below the Kagati Lake mercury prospect and the corresponding heavy-mineral-concentrate sample that was slightly enriched in tungsten (100 ppm) (Jones and Kilburn, 1992). Vein material collected by Frost (1990) at the Kagati Lake prospect was anomalous in silver (3 ppm), arsenic (2,000 ppm), gold (2.90 ppm), and antimony (>20,000 ppm); analysis did not include mercury. The Kagati Lake prospect ore body is generally similar to the epithermal mercury-antimony deposits discussed previously. Mineralized veins occur in a jointed quartz monzonite and granodiorite stock of Late Cretaceous age, intruding graywacke, shale, and volcanic rocks of the Togiak terrane. Most of the ore occurs in small veins and fractures in a northwest-trending shear zone. Ore minerals include cinnabar, realgar, stibnite, and subordinate amounts of orpiment and secondary antimony minerals (Sainsbury and MacKevett, 1965). The limited size of the deposit, originally staked in 1927, has so far prohibited the recovery of mercury (Hoare and Cobb, 1977; Eberlein and others, 1977).

The second anomaly in Area 4 is located almost 8 km (5 mi) northnortheast of the Kagati Lake prospect and related mercury anomaly discussed above. In this part of Area 4 nearly half of the stream sediment molybdenum anomalies identified in the study area were detected in samples collected from an unnamed drainage which flows northeast into Trail Creek (3 sample sites with 15-20 ppm Mo). Stream-sediment samples from this drainage also contain anomalous amounts of gold (0.15 ppm), arsenic (1,500 ppm), and copper (200 ppm). Anomalous arsenic (1,000 ppm) was also noted in one of the corresponding heavy-mineral-concentrate samples (Jones and Kilburn, 1992). The small basin where the anomalous samples were collected is largely covered by unconsolidated glacial material and underlain by a granitoid stock and associated hornfels zone, as well as sedimentary and volcanic rocks of the Togiak terrane. The major northwest-trending Trail Creek fault intersects the drainage near its mouth (Hoare and Coonrad, 1978). About 1 km (0.6 mi) south of the drainage containing the anomalous molybdenum, a heavy-mineral-concentrate sample with anomalous silver, copper, lead, antimony, and zinc was collected (Jones and Kilburn, 1992), providing some evidence for mineralized rock in the region immediately east of the Kagati Lake deposit.

Area 5, a single-site mercury anomaly (1.0 ppm) located on the east side of the Izavieknik River valley just north of Upper Togiak Lake, is near the Togiak-Tikchik fault zone, a major northeast-trending structural feature that cuts volcanic and sedimentary rocks of the Togiak terrane. There is no record of mining activity or mineral occurrences in Area 5. However, heavy-mineral-concentrate anomalies in Area 5 include (1) barium (5,000 ppm), copper (1,500 ppm), and molybdenum (20 ppm) detected at the same site as the stream-sediment mercury anomaly; (2) a copper-zinc enrichment extending the length of the ridge that encloses the west side of the Izavieknik River valley; and (3) high levels of barium, copper, and arsenic noted in a drainage that flows west into Upper Togiak Lake, 3 km (2 mi) south of the mercury anomaly (Jones and Kilburn, 1992). One rock sample (argillite), gathered near the mouth of this same west-flowing drainage, was anomalous in mercury (1.5 ppm), molybdenum (20 ppm), and zinc (110 ppm) (Coonrad and others, 1978). Although Area 5 is delineated on the basis of anomalous mercury in a single stream-sediment sample, nearby geochemical anomalies in heavy-mineral-concentrate and rock samples supports the designation of a separate area in this report.

Area 6 is a narrow, discontinuous tract in the southeast part of the study area, extending southward about 50 km (30 mi) from the No Lake Region to Bristol Bay. More than half (8) of the stream-sediment mercury anomalies detected in the study area are found in Area 6. These 8 samples contained measured concentrations of mercury ranging from 0.55 ppm to 2 ppm. Area 6 is underlain by Jurassic and Early Cretaceous volcanic and sedimentary rocks of the Togiak terrane. Anomalous concentrations of no other elements are detected in the stream-sediment samples collected in the area, although anomalous barium (ranging from 3,000 ppm to 5,000 ppm) is found in some corresponding heavy-mineral-concentrate samples collected in the upper Kulukak River basin (Jones and Kilburn, 1992). The correlation between the barium and mercury is unclear although barium is frequently found near the top of vertically zoned hydrothermal systems (Rose and others, 1979). Of greater significance is the high concentration of mercury found in rock samples collected 5 km (3 mi) northwest of Area 6, especially one sample of sheared diorite that contained >10 ppm mercury (Coonrad and others, 1978). A volcanic geothermal area is identified by Conwell and Schell (1977) a few kilometers west of Area 6, along the Togiak-Tikchik fault zone. This geothermal area coincides with the Pleistocene Togiak River valley basalt field and related volcanic vent (Hoare and Coonrad, 1978).

### Area 7

A gold-arsenic-lead anomaly (Area 7) is centered on the Mt. Waskey-Rainbow Basin area and extends south for about 32 km (20 mi) to Sunshine Valley in the east-central part of the study area. Stream-sediment samples contain as much as 1.5 ppm gold, 2,000 ppm arsenic, and 35 ppm lead. Arsenic, silver, bismuth, tin, lead, tungsten, antimony, copper, molybdenum, and zinc, are anomalous in many corresponding heavy-mineral-concentrate samples, particularly in drainages in the vicinity of Mt. Waskey and Rainbow Basin. There is little record of prospecting in this part of the study area, although small quantities of placer gold were reported in creeks that drain the ridge southwest of Sunshine Valley and streams entering Lake Elva (Hoare and Cobb, 1977). In addition, placer gold and a single occurrence of molybdenite (vein?) are reported several kilometers to the east, in the adjacent Dillingham quadrangle (Eberlein and others, 1977).

Area 7 is underlain by the accreted Togiak tectono-stratigraphic terrane (Jones and others, 1987) and locally intruded by Late Cretaceous to early Tertiary felsic plutonic rocks of intermediate composition. Hornfels generated by the recrystallization of the surrounding country rock form prominent haloes that envelop the intrusive rocks. Quaternary glacial deposits consisting of reworked sand, gravel, and boulders cover much of the lowland river valleys (Hoare and Coonrad, 1978).

A spatial relationship exists between the stream-sediment and heavy-mineral-concentrate geochemical anomalies and nearby granitic intrusives. It is presently unclear if the geochemical anomalies are related to some type of polymetallic mineralization in the intrusive bodies and (or) surrounding contact aureoles. The geochemical anomalies in Area 7 may reflect occurrences similar to the so-called "red spots" found in the Bethel quadrangle immediately north of the study area (Frost, 1990). The "red spots" are described by Frost (1990) as oxidized pyrite-bearing rhyolite dikes and sulfide-rich quartz veins that frequently occur as integrated dike-vein networks hosted in volcanic, volcaniclastic, and sedimentary rocks of the Togiak and Tikchik terranes. The dike-vein systems bear a collective trace element signature (Ag-As-Au-Cu-Hg-Mo-Pb-Sb-W) practically identical to that of the geochemical anomaly identified in the Mt. Waskey-Sunshine Valley region. Mertie (1938) noticed a conspicuous reddening of the country rocks bordering granitic bodies near Area 7 in Sunshine Valley and Akuluktok Mountain, which he attributes to iron oxides and hydroxides precipitated along cleavage, joint, and bedding planes of altered sedimentary rocks. Hoare and Coonrad (1961) on the other hand, report that rhyolitic rocks, including rhyolite dikes, are relatively rare geologic features of the Bristol Bay region. Most of the dike-vein associations of the Bethel quadrangle, possess small surface expressions (Frost, 1990); if comparable systems are present in the Mt. Waskey-Sunshine Valley region they could easily be missed or overlooked in the coarse of a regional mapping survey.

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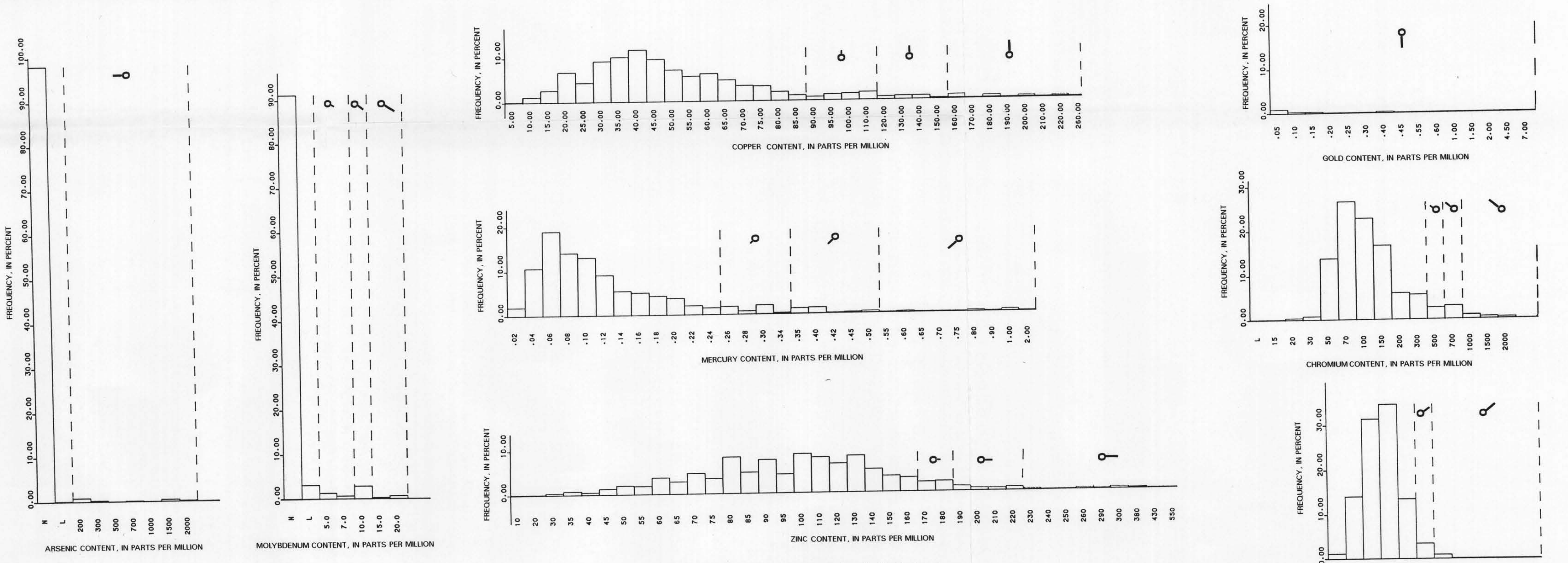

Figure 3. Histograms showing the distribution of values determined for the elements shown on the accompanying map. The length of the vectors shown on the histograms indicates the concentrations of each element plotted on the map. N, not detected at lower limit of determination; L, observable, but lower than limit of determination.

# GEOCHEMICAL MAP SHOWING THE DISTRIBUTION OF SELECTED ELEMENTS IN STREAM SEDIMENTS FROM THE GOODNEWS BAY, HAGEMEISTER ISLAND, AND NUSHAGAK BAY QUADRANGLES, ALASKA

By

James E. Kilburn and Janet L. Jones

1992

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