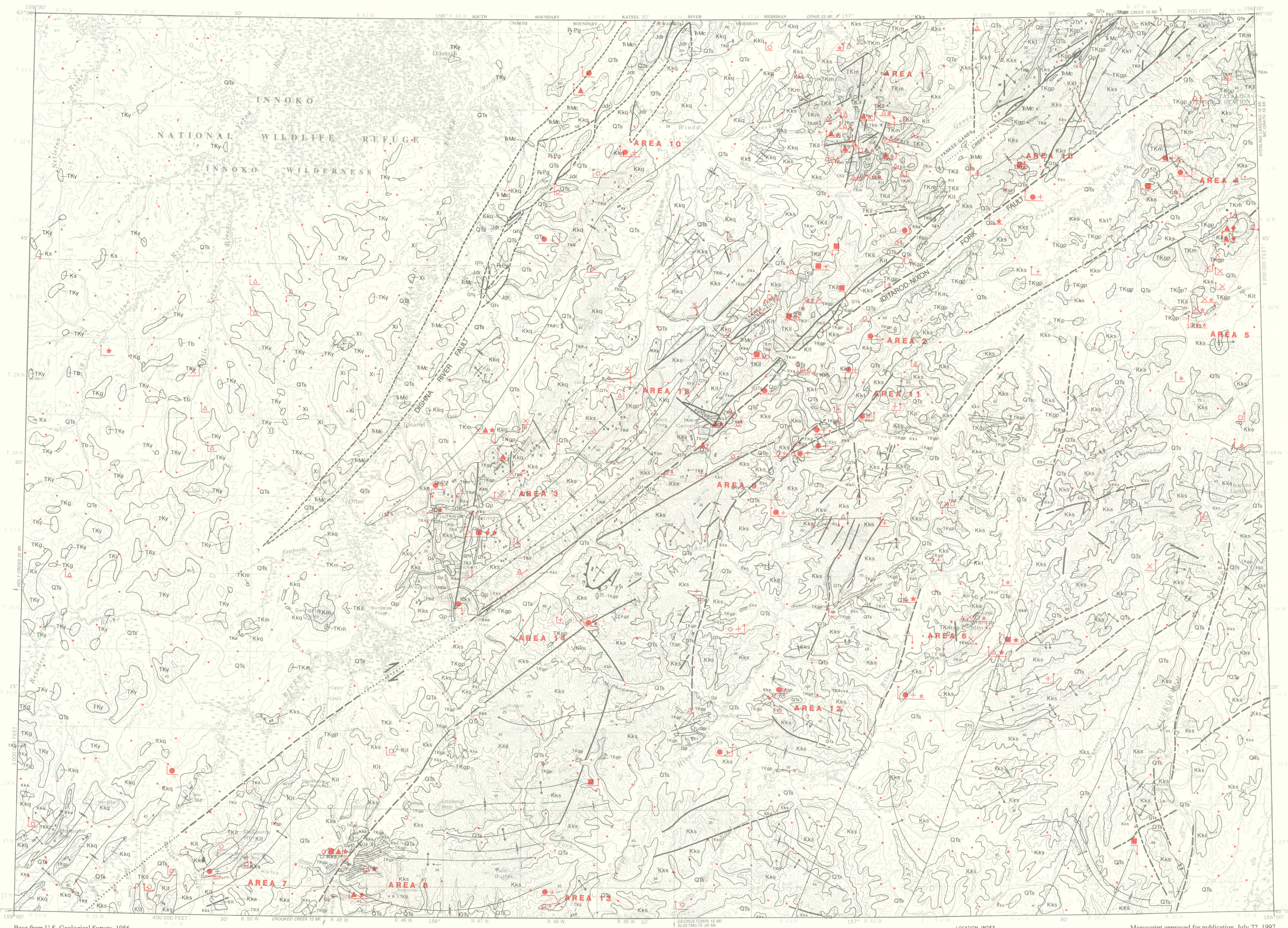
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-2219-C



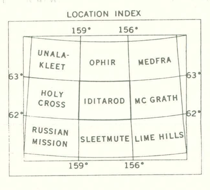
Base from U.S. Geological Survey, 1956

SCALE 1:250 000

5 0 5 10 15 20 25 MILES

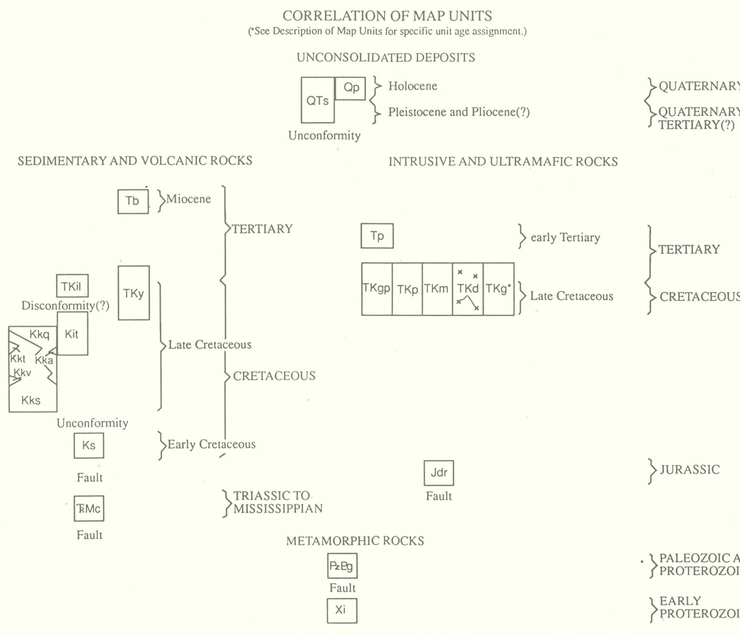
5 0 5 10 15 20 25 KILOMETERS

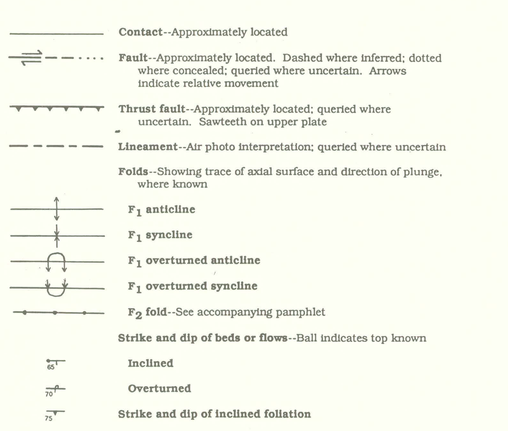
CONTOUR INTERVAL 200 FEET



Manuscript approved for publication, July 22, 1997

Geologic base from Miller and Bundtzen, 1994





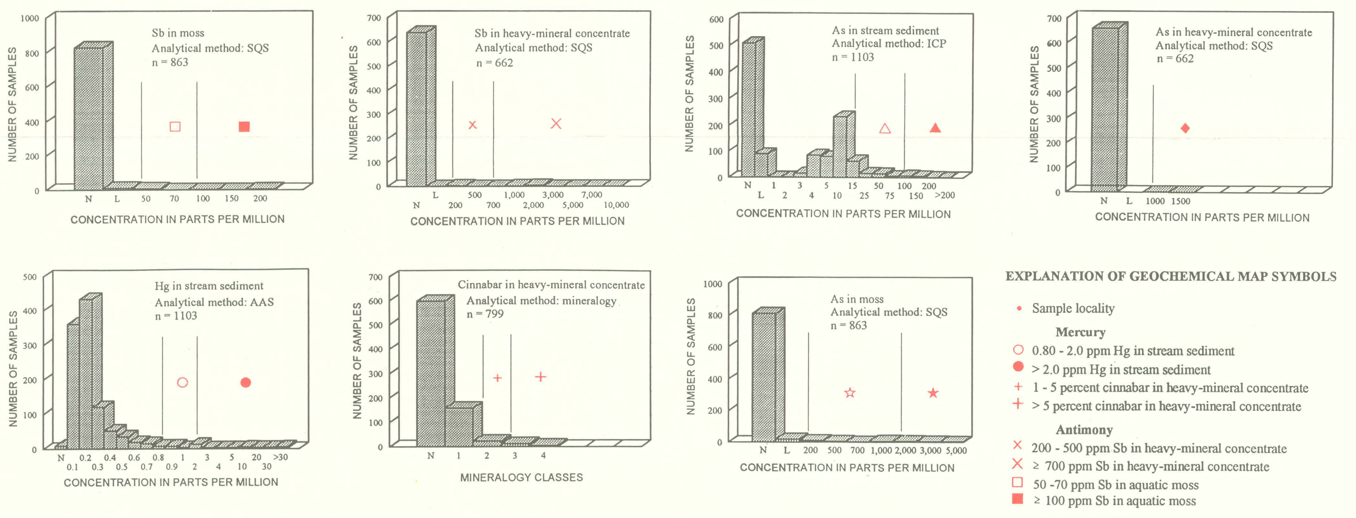


Figure 2. Histograms showing frequency distribution of Hg, Sb, As, and cinnabar in various sample media. Symbols on histograms show anomaly selections and are the same as those on the map. [N, not detected at the lower limit of determination; L, detected but less than the lower limit of determination; n, number of samples analyzed; SQS, semiquantitative spectrography; AAS, atomic absorption spectrophotometry; ICP, inductively coupled plasma analysis. Mineralogy classes are based on estimated percentages where N = not detected, class 1 = <1%, class 2 = 1-5%, class 3 = 5-20%, class 4 = 20-50%, and class 5 = >50%].

EXPLANATION OF GEOCHEMICAL MAP SYMBOLS

- • Sample locality

Mercury

- ○ 0.80 - 2.0 ppm Hg in stream sediment
- ● > 2.0 ppm Hg in stream sediment
- + 1 - 5 percent cinnabar in heavy-mineral concentrate
- + > 5 percent cinnabar in heavy-mineral concentrate

Antimony

- × 200 - 500 ppm Sb in heavy-mineral concentrate
- × ≥ 700 ppm Sb in heavy-mineral concentrate
- □ 50 -70 ppm Sb in aquatic moss
- ■ ≥ 100 ppm Sb in aquatic moss

Arsenic

- △ 15 - 90 ppm As in stream sediment
- ▲ > 90 ppm As in stream sediment
- ◆ ≥ 1,000 ppm As in heavy-mineral concentrate
- ☆ 200 - 1,000 ppm As in aquatic moss
- ★ ≥ 2,000 ppm As in aquatic moss

Table 1. Summary of data used for Hg-Sb-As anomaly map

[All values shown are parts per million (ppm), except detection ratio, *N*, *L*, *G*, and mineralogy results (based on visual percentage estimates of cinnabar using a binocular microscope). Detection ratio is the number of unqualified values divided by the total number of samples analyzed. *N* is the number of samples in which concentrations were not detected at the lower limit of determination. *L* is the number of samples in which concentrations were reported as observable but were less than the lower limit of determination. *G* is the number of samples in which concentrations were detected, but were greater than the upper limit of determination. N, not detected at the concentration shown; L, detected but less than the concentration shown; G, greater than the concentration shown; --, not applicable; n.d., no cinnabar identified; AAS, atomic absorption spectrophotometry; SQS, semiquantitative spectrography; ICP, inductively coupled plasma spectroscopy]

Element	Sample type	Detection ratio	Lower limit	*N*	*L*	*G*	Minimum	Percentiles 50th	90th	95th	98th	Maximum	Selected anomalous concentration
Hg	Stream sediment (AAS)	0.99	0.02	9	0	4	0.02	0.14	0.45	0.77	3.6	34G	0.80
	Mineralogy (cinnabar)	0.25	1 grain	598	--	--	n.d.	n.d.	<1%	1-5%	1-5%	20-50%	1-5%
Sb	Heavy-mineral concentrate (SQS)	0.03	200	640	1	0	200N	200N	200N	200N	700	10,000	200
	Moss (SQS)	0.03	50	829	12	0	50N	50N	50N	50N	50	200	50
	Stream sediment (ICP)	0.46	2.0	508	89	0	2.0N	3.2	10	15	50	210	15
As	Heavy-mineral concentrate (SQS)	0.005	500	659	0	0	500N	500N	500N	500N	500N	1,500	1,000
	Moss (SQS)	0.04	200	810	18	0	200N	200N	200N	200L	700	5,000	200

DESCRIPTION OF MAP UNITS

(Geology is shown in gray on the map)

UNCONSOLIDATED DEPOSITS

Qp **Placer mine tailings (Holocene)**—Symmetrical to irregular piles of artificially water worked, sorted gravel and in situ slab rock derived from bedrock. Fine silt and sand fractions partially removed during placer mining process. Tailings in most drainages range from 1 to 4 m thick

QTs **Surficial deposits (Holocene to Pliocene?)**—Unconsolidated fluvial, terrace, colluvial, glacial, and eolian deposits usually covered by vegetation. Surficial deposits generally range from 3 to 20 m thick and exhibit at least some degree of permafrost, depending on slope orientation and composition. Glacial deposits occur mainly in the Beaver Mountains and nearby highlands. Age of unit is primarily Pleistocene and Holocene; some Pliocene deposits may also be present locally

SEDIMENTARY AND VOLCANIC ROCKS

Tb **Basaltic andesite (Miocene)**—Scattered exposures of very fine grained to aphanitic, dark- to medium-gray, locally vesicular, augite basaltic andesite in west-central part of study area. Unit is undeformed and unaltered except for local devitrification

TKy **Volcanic rocks of Yetna River area (early Tertiary and Late Cretaceous)**—Chiefly subaerial lava flows of andesite, dacite, rhyolite, and minor basalt and subordinate welded to nonwelded rhyolitic to andesitic ash-flow tuffs. Outcrops and rubble found mainly in stream bluffs and occasionally on rounded hill tops as tors; columnar-jointed andesite is present near VABM Reindeer (T. 28 N., R. 50 W.). Unit thickness roughly estimated at 500 m

Iditarod Volcanics (early Tertiary and Late Cretaceous)—Dominantly subaerial volcanic rocks consisting of a heterogeneous basal unit (tuff, altered flows, and volcaniclastic rocks) overlain by mafic and intermediate lava flows. Iditarod Volcanics are 500–600 m thick and overlie sedimentary rocks of Kuskokwim Group. In this area, divided into:

TKil **Andesitic to basaltic subaerial lava flows and mafic volcanic breccia (early Tertiary and Late Cretaceous)**—Subaerial, locally columnar jointed, aphanitic to porphyritic, olivine-clinopyroxene basaltic andesite, clinopyroxene andesite, and minor dacite; volcanic breccia locally interfingers with flow rocks. Unit is generally resistant, forming prominent blocky outcrops and tors near ridgetops. Unit is roughly 150 to 250 m thick and contact with underlying unit **Kit** may be disconformable.

Kit **Tuff, volcanic breccia, altered andesitic to dacitic flows, and volcaniclastic sandstone (Late Cretaceous)**—Heterogeneous assemblage characterized by tuff (lithic, crystal, and water-laid) and altered intermediate lava flows; locally includes volcanic breccia, volcaniclastic sandstone, and lahar deposits. Total unit thickness estimated to be around 350 m. Unit may be correlative with unit **Kka**

Kuskokwim Group (Late Cretaceous; Campanian to Cenomanian)—In map area, the Kuskokwim Group consists predominantly of sedimentary rocks but also has minor, interbedded volcanic tuff and flow rocks primarily in upper part of section. The sedimentary rocks represent turbidite fan, foreslope, shallow-marine, and shelf facies deposited in a Late Cretaceous basin. The Kuskokwim Group is estimated to average 2,200 m in thickness northeast of the Iditarod-Nixon Fork Fault, but may be as much as 5,000 m thick southeast of the fault. In this area, divided into:

Kkq **Quartzose sandstone and siltstone (Late Cretaceous; Campanian to Turonian?)**—Quartzose sublithic sandstone, conglomerate, siltstone, and siliceous shale representing shallow-marine and locally non-marine facies. Unit is estimated to be 600 m thick and basal part interfingers with deeper water facies rocks of unit **Kks**. Lower age limit of unit is speculated to be Turonian based on interfingering with unit **Kks**. Upper age limit at least as young as Campanian but not younger than Paleocene.

Kks **Sandstone, siltstone, shale, and conglomerate (Late Cretaceous; Campanian? to Cenomanian)**—Thick assemblage of fine- to coarse-grained lithic sandstone, micaceous siltstone, shale, and minor chert-pebble conglomerate that forms the major part of the Kuskokwim Group in the map area. Structures and compositions indicate that unit **Kks** was primarily deposited by turbidity currents. Total thickness of unit is poorly known but may be as much as 5,000 m. Upper age limit is not clearly defined but must be older than the youngest part of unit **Kkq**, which generally overlies unit **Kks**

Kkt **Volcanic tuff and agglomerate (Late Cretaceous)**—Heterogeneous assemblage of tuff, agglomerate, cherty tuff, and locally minor sandstone that crops out in isolated areas. Lithologically and petrographically identical to unit **Kit**; the two units are distinguished only by their associated rocks. Unit **Kkt** is apparently interbedded with sedimentary rocks (**Kks**) of Kuskokwim Group, whereas unit **Kit** is spatially associated with massive flow rocks of unit **TKil** but could either overlie, or locally interfinger with, the Kuskokwim Group. Unit assigned a Late Cretaceous age based on apparent interbedded relation with unit **Kks**

Kka **Altered andesite flows, tuffs, and sills(?) (Late Cretaceous; Campanian)**—Unit crops out in the Mosquito Mountain area (southwestern part of the quadrangle) and consists of 1- to 5-m-thick layers of intermediate igneous rocks apparently interbedded with unit **Kkq**. The flows and tuffs are andesitic in composition and have 15–30 percent phenocrysts of plagioclase, oxidized amphibole, clinopyroxene, magnetite, and local biotite in a groundmass of felted plagioclase laths, opaque oxides, and accessory apatite. Tuffs characterized by broken crystals and abundant andesite lithic fragments

Kkv **Volcanic flow(s) and tuff (Late Cretaceous)**—Hornblende-clinopyroxene andesitic volcanic flow(s) and chlorite-, calcite-altered tuff. Unit poorly exposed and found only in one area (T. 27 N., R. 42 W.); estimated to be no more than 20 m thick. Assigned a Late Cretaceous age based on apparent interbedded relation with unit **Kks**

Ks **Sandstone and siltstone (Early Cretaceous)**—Medium-grained to very fine grained sandstone, tuffaceous sandstone, and siltstone exposed only as colluvial chips in western part of map area

TrMc **Chert, volcanic rocks, metasandstone, and limestone (Triassic to Mississippian)**—Radiolarian chert (partly to wholly recrystallized), clinopyroxene basalt to basaltic andesite, lithic tuff, water-laid tuff, metasiltstone, and minor fossiliferous shallow-water limestone. Unit primarily exposed along the Dishna River Fault Zone in the north-central part of the map area; however, six small occurrences, interpreted as fault slivers, are scattered throughout the northeastern part of the quadrangle. Prehnite-pumpellyite facies metamorphism is indicated by presence of secondary prehnite, chlorite, clinozoisite, and pumpellyite in the volcanic rocks. Unit is correlative with the Innoko terrane of Jones and others (1987) and Patton and others (1989b)

INTRUSIVE AND ULTRAMAFIC ROCKS

Tp **Porphyritic granodiorite plug (early Tertiary)**—Unit consists of one exposure in T. 28 N., R. 46 W. Small granodiorite body containing abundant phenocrysts of hornblende and albitic plagioclase in finer-grained, phaneritic groundmass

TKgp **Hypabyssal granite porphyry dikes, sills, and plugs (early Tertiary and Late Cretaceous)**—Porphyritic to fine-grained phaneritic dikes, sills, and plugs of granitic composition. Phenocrysts of biotite + quartz + plagioclase + sanidine + white mica ± trace garnet compose as much as 5 percent of most dikes and 20 percent of most plugs; sericitic alteration common in groundmass. Biotite generally composes less than 5 percent of the samples, so rocks could be classified as alaskite

TKp **Pilotaxitic dacite-andesite plugs (early Tertiary and Late Cretaceous)**—Three small bodies of subvolcanic dacite to andesite are exposed in the east-central part of the quadrangle. Unit is moderately resistant and morphology of exposures suggests they are hypabyssal intrusive bodies rather than volcanic flows, but they have a distinctive pilotaxitic (flow-oriented) texture to the fine-grained groundmass

TKm **Monzonite, quartz monzonite, syenite, granodiorite, granite, and minor lamprophyre (early Tertiary and Late Cretaceous)**—Small stocks and plutons of fine- to coarse-grained, phaneritic to hypidiomorphic, clinopyroxene-biotite ± olivine monzonite, hornblende-clinopyroxene-biotite quartz monzonite, biotite syenite, biotite-hornblende granodiorite, biotite granite, and rare lamprophyric rocks. Composite intrusive rocks are in part overlain by, and in part intrude coeval volcanic rocks (Iditarod Volcanics)

TKd **Altered intermediate to mafic dikes (early Tertiary and Late Cretaceous)**—Porphyritic biotite-clinopyroxene-plagioclase ± olivine dikes, which are partly to extensively altered to chlorite-calcite-silica assemblages. Original compositions were probably intermediate to mafic. Dikes generally are less than 1 m thick, discontinuous, and usually cannot be traced for more than 10 m. Presence of dike is indicated by "x" on the map for visual emphasis, but extent of actual exposures is exaggerated

TKg **Alkali granite (early Tertiary and Cretaceous)**—Poorly exposed, medium-grained, granophyric alkali granite found as discontinuous rubble cropping out under heavily vegetated cover in the western part of the map area. All rocks of the unit are light colored (color index <7 percent), but the mafic minerals vary locally. In the southwestern part of the quadrangle (T. 24 N., R. 53 W. and T. 25 N., R. 52 W.) mafic minerals consist of alkali amphibole, pyroxene, and biotite, but exposures farther north have biotite (chloritized) only

Jdr **Dishna River mafic and ultramafic rocks (Jurassic)**—Assemblage of poorly exposed mafic and ultramafic rocks in north-central part of quadrangle. Mafic and ultramafic rocks are probably ophiolitic in origin but now occur as isolated, fault-bounded blocks that lie along the Dishna River Fault Zone. Mafic rocks include two-pyroxene gabbronorite, clinopyroxene + hornblende gabbro, hornblende gabbro, and diabase. Ultramafic rocks include harzburgite, minor dunite, and rare pyroxenite, all partially to completely serpentinized. Unit assigned a Jurassic age based on correlation with lithologically similar mafic and ultramafic complexes that lie north of the map area (the Tozitna-Innoko belt described by Patton and others, 1989a)

METAMORPHIC ROCKS

PzPg **Greenschist, pelitic schist, and metagranite (Paleozoic and Proterozoic?)**—Generally poorly exposed, mixed assemblage of greenschist facies metamorphic rocks including mafic meta-igneous rocks, subordinate metasedimentary rocks (pelitic schist, phyllite, calcareous schist, and quartzite), and minor granitic orthogneiss. Mafic schists commonly exhibit secondary mineral assemblages of epidote-chlorite-hornblende/actinolite-albitic plagioclase-quartz ± biotite ± sphene, indicative of middle greenschist facies, but assemblages characteristic of lower and upper greenschist facies also occur. Unit is correlative with rocks of the Ruby terrane as outlined by Jones and others (1987) and Patton and others (1989b), and is therefore assigned the same age. Unit assigned a Proterozoic(?) and Paleozoic age based on correlation with rocks of the Ruby terrane

Xi **Idono Complex (Early Proterozoic)**—Foliated metaplutonic rocks, lesser amphibolite, and minor metasedimentary rocks. Outcrop exposure is limited to a dozen localities; frost-riven rubble is sparse but widespread. The compositionally diverse metaplutonic rocks consist primarily of biotite ± muscovite granitic orthogneiss but also include orthogneisses of tonalite, granodiorite, quartz diorite, and quartz monzonite, minor metagabbro, and rare hornblendite. Texturally, metaplutonic rocks range from slightly foliated varieties to blastomylonitic augen gneiss. Amphibolite varies little in composition and consists of moderately foliated to well-foliated epidote-biotite-hornblende-intermediate plagioclase ± garnet ± sphene. The well-foliated, semipelitic metasedimentary rocks include muscovite-biotite-feldspar-quartz ± garnet ± epidote schists. Metamorphic grade of the Idono Complex is amphibolite facies

STUDIES RELATED TO AMRAP

The U.S. Geological Survey (USGS) is required by the Alaska National Interests Lands Conservation Act (Public Law 96-487, 1980) to survey certain federal lands to determine their mineral potential. Results from the Alaska Mineral Resource Assessment Program (AMRAP) must be made available to the public and be submitted to the President and Congress.

This is one of a series of maps that present geological and geochemical results from the mineral resource assessment study of the Iditarod quadrangle, Alaska. This report shows the distribution of anomalous concentrations of Hg, Sb, and As determined from the geochemical analysis of stream-sediment, nonmagnetic heavy-mineral-concentrate, and aquatic-moss samples, as well as anomalous concentrations of cinnabar in the nonmagnetic heavy-mineral-concentrate samples, collected from the quadrangle. Other reports in this series on the Iditarod quadrangle include a geologic map (Miller and Bundtzen, 1994), a mineral resource assessment of the quadrangle (Miller and others, in press), a Au-Ag anomaly map (Gray, Motooka, and O'Leary 1997), and a Cu-Pb-Zn-Sn-W anomaly map (Gray, Ryder, and Taylor, 1997). The geologic map from Miller and Bundtzen (1994) is used as a base map for interpretations in this study.

INTRODUCTION

During the summers of 1984-86, a reconnaissance geochemical survey was conducted in the Iditarod 1° X 3° quadrangle, Alaska. The quadrangle is bounded by latitudes 62°N and 63°N and by longitudes 156°W and 159°W. The study area is about 6,700 mi^2 (17,350 km^2) in southwestern Alaska and it includes the Beaver Mountains and part of the Kuskokwim Mountains (see map). Part of the Innoko National Wildlife Refuge is in the northwestern corner of the quadrangle. Few roads exist in the quadrangle and access to much of the study area is limited to travel by aircraft or by foot on various trails. Boat access is possible on some larger rivers.

The terrain is dominated by low rolling hills and broad, sediment-filled lowlands. This terrain is best exemplified by the Kuskokwim Mountains in the central part of the quadrangle. Rugged topography characterizes the Beaver Mountains and a few other mountain peaks scattered throughout the quadrangle. The maximum elevation in the quadrangle is 4,055 ft (1,236 m) in the northern Beaver Mountains. Much of the western part of the quadrangle is low and swampy, particularly in the Yetna and Iditarod River basins where the minimum elevation is about 100 ft (30 m). Most of the quadrangle is covered with vegetation that ranges from northern latitude forest to subarctic tundra.

GENERAL GEOLOGY

The map shows the geology of the quadrangle as described by Miller and Bundtzen (1994). The following descriptions are summarized from their work, but additional details of the geology of the quadrangle are given in Miller and Bundtzen (1994). Bedrock of the Iditarod quadrangle can be broadly subdivided into (1) displaced slices of pre-Cretaceous rocks that are found in narrow fault bounded belts, and (2) overlap assemblages of Cretaceous and younger sedimentary, volcanic, and plutonic rocks that constitute about 95 percent of the bedrock in the quadrangle (Miller and Bundtzen, 1994). The overlap assemblages have experienced at least two periods of open to isoclinal folding that includes a well-expressed generally northeast-trending earlier event and a poorly expressed north-trending later event. The Iditarod-Nixon Fork Fault is a major northeast-trending strike-slip fault that bisects the quadrangle. The Dishna River Fault lies in the north-central part of the quadrangle and defines the southeast side of the northeast-trending belt of pre-Cretaceous rocks (Miller and Bundtzen, 1994).

Late Cretaceous sedimentary rocks of the Kuskokwim Group (Cady and others, 1955) is a regionally extensive basin-fill sequence found throughout southwestern and west-central Alaska and is the dominant bedrock in the Iditarod quadrangle. Rocks of the Kuskokwim Group represent turbidite fan, foreslope, shallow-marine, and shelf facies deposited in a Late Cretaceous basin, but subordinate shallow-marine and fluvial strata were deposited along the basin margins (Miller and Bundtzen, 1994). Rocks of the Kuskokwim Group consist primarily of intercalated sandstone, shale, chert, and conglomerate (Kks, Kkq), but they also include interbedded volcanic tuff and flow rocks (Kka, Kkt, Kkv). Volcano-plutonic complexes intrude or overlie rocks of the Kuskokwim Group at many localities such as the Beaver Mountains, Camelback Mountain, Swinging Dome, Chicken Mountain, Granite Mountain, Mount Joaquin, Takotna Mountain, and VABM Tatalina (Miller and Bundtzen, 1994). Volcanic rocks of these complexes consist primarily of Late Cretaceous and early Tertiary andesitic to basaltic flows (Kit and TKil) that together constitute the Iditarod Volcanics (Miller and Bundtzen, 1994). The volcanic rocks are generally in fault contact with or overlie comagmatic monzonite, quartz monzonite, syenite, granodiorite, granite, and minor lamprophyric plutons (TKm). At the contacts with the plutons, volcanic and sedimentary rock hornfels are common. Other Late Cretaceous and Tertiary igneous rocks include: (1) an extensive field of felsic to mafic volcanic rocks of the Yetna River area (TKy) that covers much of the western part of the quadrangle, (2) small dikes of intermediate to mafic composition (TKd) found throughout the quadrangle, (3) granite porphyry dikes, sills, and plugs (TKgp), (4) dacite-andesite plugs (TKp), and (5) alkali granite (TKg) in the western part of the quadrangle (Miller and Bundtzen, 1994). Minor exposures of Early Cretaceous sandstone and siltstone (Ks), Miocene basaltic andesite (Tb), and a small early Tertiary granodiorite plug (Tp) are also found in the quadrangle.

Volumetrically minor pre-Cretaceous rocks are divided into four narrow, northeast-trending fault bounded units in the west-central part of the quadrangle. The two older units (Proterozoic to Paleozoic age) are metamorphosed continental rocks and the younger two units (Mississippian and Jurassic age) are oceanic in origin (Miller and Bundtzen, 1994). The oldest rocks are Early Proterozoic rocks of the Idono Complex (Xi), which is a fragment of metamorphosed continental crust that consists of amphibolite grade granitic to dioritic orthogneiss, amphibolite, and metasedimentary rocks (Miller and Bundtzen, 1994). Isotopic data indicate a protolith age of 2.06 Ga for granitic orthogneiss in the complex (Miller and others, 1991). Another belt of continental rocks consists of greenschist facies meta-igneous and metasedimentary rocks of middle Paleozoic and possibly Proterozoic protolith age (PzPg). These rocks are characterized by mafic greenschist, lesser pelitic schist, phyllite, calcareous schist, quartzite, and minor granitic orthogneiss that are possibly correlative with rocks of the Ruby terrane of Jones and others (1987). Mississippian to Triassic oceanic crustal and volcanic-arc rocks (TrMc) are also found in the belt of pre-Cretaceous rocks (Miller and Bundtzen, 1994). These rocks consist of radiolarian chert, basalt to basaltic andesite, lithic tuff, metasiltstone, and minor limestone that are correlative with rocks of the Innoko terrane of Jones and others (1987). Mafic and ultramafic rocks (Jdr) of the Dishna River area are the youngest of the pre-Cretaceous rocks (Miller and Bundtzen, 1994). These rocks consist generally of greenschist facies mafic rocks and serpentinized ultramafic rocks of probably ophiolitic origin that are correlative with the Jurassic ophiolites of the Tozitna-Innoko belt of Patton and others (1989a).

MINERAL DEPOSITS

Gold and silver are the most economically significant commodities in the Iditarod quadrangle, for example, over 1,600,000 oz of gold (49,700 kg) and 240,000 oz (7,500 kg) of silver have been produced mostly from placer mines in the quadrangle (Miller and Bundtzen, 1987; Bundtzen, Cox, and Veach, 1988; Bundtzen and Miller, 1997); additional estimated gold reserves in the quadrangle exceed 4,500,000 oz (140,000 kg) (Bundtzen and Miller, 1997). However, epithermal cinnabar and stibnite vein deposits, representing significant Hg and Sb resources, are found in a belt covering several tens of thousands of square kilometers in the Kuskokwim River region, which includes part of the Iditarod quadrangle (Sainsbury and MacKevett, 1965). The first cinnabar lode in the region was discovered in 1838 by Russian traders on the Kuskokwim River at Kolmakof (fig. 1) in the Sleetmute quadrangle (Cady and others, 1955), about 30 mi (48 km) south of the Iditarod quadrangle. Since that time, numerous cinnabar and stibnite deposits have been discovered in the Kuskokwim River region quadrangle (Sainsbury and MacKevett, 1965). Over 41,000 flasks of Hg (1 flask weighs 76 lbs or 34.5 kg) have been produced from mines in the Kuskokwim River region, although most of the Hg (about 36,000 flasks) was recovered from the Red Devil mine in the Sleetmute quadrangle (Miller and others, 1989; Gray and others, 1997). Additional discoveries of cinnabar and stibnite mineral occurrences are likely in the Iditarod quadrangle and throughout southwestern Alaska because the region has not been well explored and the rocks are poorly exposed or covered with vegetation. Cinnabar- and stibnite-bearing deposits and mineral occurrences are the most important type of mineral deposit for interpretations of the geochemistry presented this report.

Deposits of Hg and Sb are found generally in sedimentary rocks of the Late Cretaceous Kuskokwim Group and Late Cretaceous and early Tertiary mafic to felsic dikes, sills, or small stocks that intrude these sedimentary rocks (Sainsbury and MacKevett, 1965; Gray and others, 1997). Gray and others (1997) used geochemical, isotopic, and age data to suggest that epithermal Hg-Sb deposits in southwestern Alaska formed in response to Late Cretaceous and early Tertiary subduction-related arc magmatism. Cinnabar and stibnite are the dominant ore minerals in veins and vein breccias containing abundant quartz and carbonate gangue; subordinate realgar, orpiment, native mercury, pyrite, gold, hematite, limonite, and dickite are found locally (Sainsbury and MacKevett, 1965; Gray and others, 1990). The DeCourcy Mountain mine (T. 23 N., R. 50 W.; fig. 1) is the most significant Hg mine in the Iditarod quadrangle, having produced over 1,200 flasks of Hg (Cady and others, 1955). At DeCourcy Mountain, quartz-carbonate veins and lenses containing cinnabar and stibnite are found in altered mafic dikes and sedimentary rocks of the Kuskokwim Group (Sainsbury and MacKevett, 1965). In southwestern Alaska, detrital cinnabar in heavy-mineral concentrate samples, as well as anomalous concentrations of Hg, Sb, and As in stream-sediment samples, are most diagnostic when exploring for epithermal cinnabar-stibnite vein deposits (Gray and others, 1991); these results are consistent with the mineralogy of the deposits. Several cinnabar-stibnite deposits in southwestern Alaska contain significant concentrations of gold and silver (Hawley and others, 1969; Gray and others, 1990; Bundtzen and Miller, 1997; Gray and others, 1997); as a result, Bundtzen and Miller (1997) consider these deposits to be epithermal Au-Ag deposits. Epithermal cinnabar and stibnite deposits such as at DeCourcy Mountain are a type of mineral deposit that is favorable in many areas in the Iditarod quadrangle.

Stibnite-rich lodes are known in the Donlin Creek area (T. 23 N., R. 49 W.), Granite Creek (T. 26 N., R. 42 W.), Julian Creek (T. 25 N., R. 44 W.), and at the Independence gold mine (T. 33 N., R. 38 W.) (Cady and others, 1955; Bundtzen and others, 1986; Bundtzen and Miller, 1997). The Independence mine was briefly operated in 1912 and produced about 161 oz of Au (5 kg) (Bundtzen and Miller, 1997). The lodes consist of small quartz-carbonate veins and vug fillings containing stibnite in granite porphyry dikes, adjacent sedimentary rocks, or at contacts between the two rock types. Clay and sericite gangue are local. Stibnite-rich samples from the Donlin Creek area and Granite Creek have anomalous concentrations of Au and Ag (Cady and others, 1955; Bundtzen and others, 1986; McGimsey and others, 1988; Gray and others, 1990; Bundtzen and Miller, 1997). Stibnite-rich lodes, especially those containing significant gold, are an important deposit type in the Iditarod quadrangle and throughout the Kuskokwim River region. Bundtzen and Miller (1997) describe such deposits as granite-porphyry-hosted Au-polymetallic deposits.

In addition to Hg-Sb dominant lodes, minor amounts of cinnabar and stibnite are associated with gold-scheelite-quartz-sulfide-bearing vein deposits in the Iditarod quadrangle, such in the Golden Horn mine (Bull, 1988; Bull and Bundtzen, 1987; Miller and Bundtzen, 1997). Such mineralized quartz-carbonate veins are found in monzonite plutons and surrounding hornfels, or in altered mafic to felsic dikes (Bundtzen and Gilbert, 1983; Bundtzen and others, 1992). These veins may contain gold, scheelite, cinnabar, stibnite, arsenopyrite, pyrite, chalcopyrite, galena, and sphalerite (Bull, 1988). Fluorite, tourmaline, and sericite are found in veins and vein breccias near the deposits (Bull and Bundtzen, 1987). The Golden Horn mine (fig. 1) is the most significant Au lode in the Flat area and the quadrangle, having produced about 2,700 oz of Au (84 kg) and 2,600 oz of Ag (81 kg) (Bundtzen and others, 1992). Bundtzen and Miller (1997) describe the Golden Horn deposit and similar deposits on Chicken Mountain as plutonic-hosted Cu-Au-polymetallic deposits. Other deposits of this type are possible throughout the Iditarod quadrangle.

In the Beaver Mountains, the Cirque prospect (T. 32 N., R. 41 W.) and similar lodes consist of quartz-tourmaline-axinite-fluorite veins and vein breccias containing chalcopyrite, pyrite, galena, and sphalerite (Bundtzen and Laird, 1982; Bundtzen and Miller, 1997). Tetrahedrite, cassiterite, arsenopyrite, scheelite, and wolframite are also found locally in these veins (Bundtzen and Gilbert, 1983). The veins are hosted in monzonite, syenite, intermediate to mafic volcanic rocks, and sedimentary rock hornfels that form a large volcano-plutonic complex in the Beaver Mountains (Bundtzen and Laird, 1982). Bundtzen and Miller (1997) designate such lodes in the Beaver Mountains, as well as similar lodes near Granite Mountain (T. 26 N., R. 40 W.), Bismarck Creek (T. 27 N., R. 42 W.), the Broken Shovel lode (fig. 1) in the Moore Creek area (T. 29 N., R. 42 W.) as plutonic-related B-enriched Ag-Sn-polymetallic deposits. Although cinnabar and stibnite are rare in these deposits, anomalous concentrations of Hg, Sb, or As have been reported from these occurrences (Bundtzen and Laird, 1982; McGimsey and others, 1988).

Detrital cinnabar is also found in heavy-mineral-concentrate samples collected from gold placer deposits in the Flat Creek (T. 27 N., R. 47 W.), Moore Creek (T. 29 N., R. 42 W.), and Ganes Creek (T. 33 N., R. 38 W.) areas (Bundtzen and others, 1992), Julian Creek (T. 25 N., R. 44 W.), in the Donlin Creek area (T. 23 N., R. 49 W.), Little Creek (T. 22 N., R. 51 W.) (Cady and others, 1955), and in the Fourth of July Creek area (T. 30 N., R. 42 W.) (Bundtzen, Laird, and Lockwood, 1988). The occurrence of placer cinnabar alone probably does not represent a significant Hg resource. However, placer cinnabar may help to delineate additional areas favorable for epithermal Hg-Sb vein, granite-porphyry-hosted Au-polymetallic, or plutonic-hosted Cu-Au-polymetallic deposits.

METHODS

Stream-sediment, heavy-mineral-concentrate, and aquatic-moss (bryophyte) samples were collected from active channels of perennial first-and second-order streams. The area of most drainage basins ranged from 1 mi^2 (2.6 km^2) to about 5 mi^2 (13 km^2). The sampling density was approximately 1 sample locality per 9 mi^2 (23 km^2).

In this study, 1,151 stream-sediment samples were collected, sieved to minus-80-mesh, ground, and chemically analyzed. There were 799 panned-concentrate samples collected that were sieved to minus-30-mesh, separated in bromoform, and then further separated magnetically to obtain a nonmagnetic heavy-mineral-concentrate sample. The nonmagnetic heavy-mineral-concentrate samples were split, and one split was ground for semiquantitative spectrographic analysis (SQS) and the other split was saved for mineralogy identification.

Aquatic-moss samples were collected at 863 sites, preferentially near or just above the present water level from boulders or dead-fall vegetation in the active stream channel. Moss from the channel walls or overbank was collected in the absence of moss within the active stream channel. Moss and sediment trapped within the moss were collected together as one sample, and the sediment was later removed by agitating the samples in water (Arbogast and others, 1991). When all of the sediment was removed, the moss samples were dried, ground, ashed, and analyzed by SQS.

All of the 1,151 stream-sediment samples collected were analyzed for Sb. However, because of numerous other element analyses, sufficient material was only available for Hg and As analyses for 1,103 stream-sediment samples. The 799 heavy-mineral-concentrate samples collected were microscopically examined for their mineralogical content, but only 662 concentrate samples contained sufficient material for Sb and As determinations. All 863 aquatic-moss samples were analyzed for Sb and As. Heavy-mineral-concentrate and moss samples were not analyzed for Hg.

Stream-sediment samples were analyzed for Hg using a cold-vapor atomic absorption spectrophotometry method described by Kennedy and Crock (1987). The stream-sediment samples were also analyzed for a multi-element suite (including As) using an inductively coupled plasma (ICP) technique modified from Church and others (1987). In addition, the stream-sediment, heavy-mineral-concentrate, and moss samples were analyzed for Sb and As using the multi-element SQS technique described by Grimes and Marranzino (1968). Geochemical data for the stream-sediment and heavy-mineral-concentrate samples are listed in Gray and others (1988), Motooka and others (1988), and Hopkins and others (1991). Mineralogy data appear in Bennett and others (1988). Geochemical data for the moss samples are found in Arbogast and others (1991). Histograms for the data used in this report are shown in figure 2.

RESULTS

The data used for this report include Hg concentrations in stream-sediment samples; Sb contents in nonmagnetic heavy-mineral-concentrate and moss samples; As concentrations in stream-sediment, heavy-mineral-concentrate, and moss samples; and the estimated abundance of cinnabar in nonmagnetic heavy-mineral-concentrate samples. No stream-sediment samples were found to contain Sb above the lower limit of determination (100 ppm), and thus Sb in stream sediment could not be used in this study. The mineralogic study revealed cinnabar as the most useful mineral indicative of upstream Hg, Sb, or As mineralized areas. Stibnite was recognized in only 15 of 799 heavy-mineral-concentrate samples and arsenopyrite was found in only 2 concentrate samples, whereas cinnabar was observed in 201 of the concentrate samples. Thus, stibnite and arsenopyrite were not beneficial for delineating areas containing anomalous Hg or Sb in this study. All anomalies were selected by identifying breaks in the frequency distribution of each data set, generally between the 95th and 98th percentiles. A summary of the data used in this report is presented in Table 1.

On the map, 16 areas contain sample localities that have anomalous concentrations of Hg, Sb, or As. All of these areas are spatially associated with Late Cretaceous and Tertiary igneous rocks that intrude sedimentary rocks of the Kuskokwim Group. Seven of the areas are near volcano-plutonic complexes and 9 are near felsic to mafic intrusions or volcanic flows. Samples from several other scattered localities contain anomalous concentrations of Hg, Sb, or As. These single-site anomalies are difficult to explain, but they may suggest the presence of less extensive cinnabar-stibnite deposits. These single-site anomalies are not discussed further.

Some of the Hg, Sb, or As anomalies overlap the Au-Ag anomalies (Gray, Motooka, and O'Leary, 1997) or Cu-Pb-Zn-Sn-W anomalies (Gray, Ryder, and Taylor, 1997). The anomalies designated in this study are numbered to be consistent (when possible) with other USGS geochemical maps in the Iditarod series. For example, area 1 (Beaver Mountains) correlates with area 1 in Gray, Motooka, and O'Leary (1997) and area 1 in Gray, Ryder, and Taylor (1997).

Area 1 is in the Beaver Mountains and is one of the largest areas designated on the map. The area is defined by sample localities that have anomalous concentrations of Hg, Sb, and As. The Beaver Mountains are underlain by a volcano-plutonic complex that includes intrusions of monzodiorite to syenite composition, intermediate to mafic volcanic rocks, and sedimentary and volcanic rock hornfels; intermediate to mafic dikes are also found in the area (Bundtzen and Laird, 1983). Several plutonic-related Ag-Sn-polymetallic prospects containing base-metal sulfides are known in the Beaver Mountains (Bundtzen and Laird, 1982; Bundtzen and Miller, 1997). In area 1, numerous samples contain anomalous concentrations of Hg, Sb, or As. Four stream-sediment samples contain 0.95-6.6 ppm Hg and 21 samples contain 15-180 ppm As. In addition, 11 moss samples contain 200-1,000 ppm As, and 2 moss samples contain 50 and 70 ppm Sb. This area was also found to have anomalous concentrations of Au and Ag (Gray, Motooka, and O'Leary, 1997) and Cu, Pb, Zn, Sn, and W (Gray, Ryder, and Taylor, 1997). Anomalous concentrations of Hg, Sb, and As in stream-sediment, heavy-mineral-concentrate, and moss samples collected in this area indicate that the Beaver Mountains are probably most favorable for the occurrence of B-enriched Ag-Sn-polymetallic deposits similar to the Cirque prospect (Bundtzen and Miller, 1997). The lack of significant amounts of cinnabar in heavy-mineral-concentrate samples collected in the Beaver Mountains suggests that the area probably has low favorability for the occurrence of epithermal Hg-Sb deposits.

Areas 2-6 are associated with volcano-plutonic complexes similar to, but generally smaller than, that in the Beaver Mountains. Area 2 includes parts of Moore, Maybe, Deadwood, and Fourth of July Creeks where placer gold has been found (Brooks, 1912; Mertie, 1936; Bundtzen, Laird, and Lockwood, 1988; Cobb, 1972). Altered volcanic rocks and silicified sedimentary rock hornfels in this area contain as much as 5.1 ppm Ag, 1.4 ppm Au, 150 ppm Cu, 200 ppm Pb, 10 ppm Hg, 32 ppm Sb, and 100 ppm As (McGimsey and others, 1988). Also in area 2 is the tetrahedrite-arsenopyrite-tourmaline-scheelite-bearing Broken Shovel vein lode where mineralized samples contain as much as 555 ppm Ag, 1.6 ppm Au, 5,590 ppm As, 4,860 ppm Cu, 1,430 ppm Pb, 2,400 ppm Sb, and 760 ppm Zn (Bundtzen, Laird, and Lockwood, 1988). In area 2 are 6 stream-sediment samples containing 0.88-7.0 ppm Hg and 5 with 18-30 ppm As. Seven heavy-mineral-concentrate samples collected in area 2 contain as much as 50 percent cinnabar, one heavy-mineral-concentrate sample contains 5,000 ppm Sb, and 8 moss samples contain 50-200 ppm Sb. A small, central part of area 2 was found to have anomalous concentrations of Au and Ag (Gray, Motooka, and O'Leary, 1997), and a Pb-Sn-W anomaly also overlaps with area 2 (Gray, Ryder, and Taylor, 1997). Area 2 is favorable for the occurrence of plutonic-related B-enriched Ag-Sn-polymetallic vein deposits as discussed by Bundtzen and Miller (1997), but possibly also epithermal Hg-Sb veins. An important feature of area 2 is the larger extent of the anomaly outlined here, in comparison to the Au-Ag anomaly and extent of known Au placer mining in the area.

Area 3 is generally centered around the well-known gold placer mines near Flat. The Golden Horn mine contains quartz-gold-scheelite-cinnabar-stibnite veins, and quartz-gold-cinnabar-stibnite veins have been found on Chicken Mountain (Bundtzen and others, 1992; Bundtzen and Miller, 1997). The lodes in this area are associated with monzonite plutons, sedimentary rock hornfels, or altered dikes. Quartz veins and vein breccias in granite porphyry and sedimentary and volcanic rock hornfels in area 3 contain as much as 2,000 ppm Ag, 50 ppm Au, 10,000 ppm Sb, 5,000 ppm Cu, 20,000 ppm Pb, 2,000 ppm Zn, 300 ppm Cd, 78 ppm Bi, 2,000 ppm W, 200 ppm Sn, and greater than 10 ppm Hg, 10,000 ppm As, and 2,000 ppm B (McGimsey and others, 1988). In this area, 2 stream-sediment samples contain 22 and greater than 34 ppm Hg, and 5 stream-sediment samples contain 20-190 ppm As. Two heavy-mineral-concentrate samples contain as much as 20 percent microscopically visible cinnabar, 1 concentrate sample contains 1,500 ppm As, and 6 concentrate samples contain 200-10,000 ppm Sb. Additionally, 3 moss samples contain 2,000-5,000 ppm As, 1 of which contains 100 ppm Sb. Gray, Motooka, and O'Leary (1997) identified a Au-Ag anomaly, and Gray, Ryder, and Taylor (1997) outlined a Cu-Pb-Sn-W anomaly in the Flat area. Thus, area 3 is favorable for plutonic-hosted Cu-Au polymetallic vein deposits (Bundtzen and Miller, 1997) and epithermal Hg-Sb veins.

Area 4 includes streams draining Mount Joaquin where Bundtzen and Laird (1983) reported a prospect that has cinnabar ore and minor arsenopyrite in monzodiorite; rock samples from the prospect contain 0.24 ppm Au and 0.8 ppm Ag. In this area, 3 stream-sediment samples contain 1.3-22 ppm Hg, and the heavy-mineral-concentrate samples collected at all 3 of these sites contained as much as 20 percent microscopically visible cinnabar. In addition, 1 stream-sediment sample contains 18 ppm As, 1 moss sample contains 100 ppm Sb, and 1 moss sample contains 200 ppm As. Area 4 also has anomalous concentrations of Au (Gray, Motooka, and O'Leary, 1997) and Zn and W (Gray, Ryder, and Taylor, 1997). However, the area 4 Hg-Sb-As anomaly is slightly larger than the Au and Zn-W anomalies, extending into additional watersheds on the south side of Mount Joaquin. Area 4 is favorable for the occurrence of epithermal Hg-Sb vein and epithermal Au-Ag vein deposits.

Area 5 includes Tatalina Mountain where a prospect in Mn-stained and brecciated hornfels contains 0.01 ppm Au and 2-5 ppm Ag, and a heavy-mineral-concentrate sample collected downstream from the prospect contains 0.01 ppm Au, 23 ppm Ag, 5,000 ppm Pb, and microscopically visible galena (Bundtzen and Laird, 1983). A silicified sedimentary rock hornfels from Tatalina Mountain contains 33 ppm Ag, 0.10 ppm Au, 1,100 ppm As, 9 ppm Bi, 0.12 ppm Hg, 500 ppm Pb, 36 ppm Sb, 200 ppm Sn, and 170 ppm Zn, and greater than 2,000 ppm B (McGimsey and others, 1988). In area 5, 1 stream-sediment sample contains 1.5 ppm Hg, and the heavy-mineral-concentrate sample collected from the same site contains greater than 5 percent microscopically visible cinnabar. Additional anomalies in area 5 include 3 stream-sediment samples containing 15-120 ppm As, 6 heavy-mineral-concentrate samples containing 700-7,000 ppm Sb, 2 heavy-mineral-concentrate samples containing 1,000 ppm As, 3 moss samples containing 200-1,000 ppm As, and 1 moss sample containing 50 ppm Sb. A small part of area 5 was delineated as anomalous in Au and Ag (Gray, Motooka, and O'Leary, 1997), and Pb, Sn, and W anomalies are also found in this area (Gray, Ryder, and Taylor, 1997). However, the area 5 Hg-Sb-As anomaly is much larger, and the area includes drainages southwest of Tatalina Mountain where granite porphyry intrusions and mafic volcanic rocks have been mapped (Miller and Bundtzen, 1994). Area 5 is favorable for the presence of epithermal Hg-Sb veins deposits, but the Tatalina Mountain area is probably also favorable for plutonic-related B-enriched Ag-Sn-polymetallic vein deposits (Bundtzen and Miller, 1997).

Area 6 is a small area on the southeast side of Granite Mountain. No mines or prospects are known in this area, but altered monzonite, vein breccias, and sedimentary rock hornfels collected in the Granite Mountain area contain as much as 0.05 ppm Au, 7 ppm Ag, 390 ppm Sb, 850 ppm As, 700 ppm Cu, 500 ppm Pb, 450 ppm Zn, 300 ppm Sn, 54 ppm Bi, 1.2 ppm Cd, and greater than 10 ppm Hg and 2,000 ppm B (McGimsey and others, 1988). The small area 6 Sb-As anomaly is identified by 4 sample localities consisting of 2 heavy-mineral-concentrate samples containing 700 and 2,000 ppm Sb, 3 moss samples containing 200-7,000 ppm As, 2 moss samples containing 50 and 200 ppm Sb, and 3 stream-sediment samples containing 19-60 ppm As. In addition, Gray, Motooka, and O'Leary (1997) described numerous Au and Ag anomalies in a large area around Granite Mountain and a Pb-Zn-W anomaly on the south side of Granite Mountain (Gray, Ryder, and Taylor, 1997). The Sb-As anomaly delineated here is much smaller than the Au-Ag anomaly or the Pb-Zn-W anomaly, and it is restricted to watersheds on the southeast side of Granite Mountain. The Granite Mountain area is favorable for the occurrence of plutonic-related B-enriched Ag-Sn-polymetallic vein deposits (Bundtzen and Miller 1997) and the geochemical anomalies in stream-sediment, heavy-mineral-concentrate, and moss samples in area 6 are consistent with this conclusion.

Area 7 is defined by samples containing anomalous concentrations of Hg. Bedrock in this area consists predominantly of intermediate to mafic volcanic flows, tuffs, and dikes that overlie and intrude sedimentary rocks of the Kuskokwim Group (Cady and others, 1955; Miller and Bundtzen, 1994). The DeCourcy Mountain Hg mine that produced over 1,200 flasks of Hg is found in this area; a placer gold prospect with minor placer cinnabar has also been reported on Little Creek (Maddren, 1911; Cady and others, 1955). In addition to mineralized rocks at DeCourcy Mountain, altered sedimentary and volcanic rocks containing quartz-calcite veins collected in the area contain as much as 110 ppm As, 0.92 ppm Hg, and 10 ppm Sb (McGimsey and others, 1988). In this area, 5 stream-sediment samples contain 0.80-5.1 ppm Hg, and 1 heavy-mineral-concentrate sample contains greater than 5 percent microscopically visible cinnabar. Gray, Motooka, and O'Leary (1997) report a single locality Au anomaly on Little Creek. Other significant geochemical anomalies were not found in stream-sediment and heavy-mineral-concentrate samples collected in area 7. Area 7 is favorable for epithermal Hg-Sb vein deposits.

Stream-sediment and moss samples containing anomalous concentrations of Hg, Sb, or As in the vicinity of Donlin Creek define area 8. Bedrock in this area consists of sedimentary rocks of the Kuskokwim Group intruded by several granite porphyry dikes. Stibnite prospects containing anomalous concentrations of Au, Ag, Hg, Sb, and As are known in this area (Cady and others, 1955; McGimsey and others, 1988; Gray and others, 1990). Placer gold mines in this area have recovered over 24,000 oz of gold (750 kg) (Bundtzen and Miller, 1997) and a gold lode deposit in the Donlin Creek area is estimated to contain about 3,600,000 oz of gold (112,000 kg) (Bundtzen and Miller, 1997; Millholland and Freeman, 1997). In area 8, there are 3 stream-sediment samples containing 41-110 ppm As, 1 of which contains 1.6 ppm Hg, 1 moss sample contains 200 ppm Sb, and 3 moss samples contain 2,000-5,000 ppm As. In addition, Gray, Motooka, and O'Leary (1997) delineate part of area 8 as having anomalous concentrations of Au and Ag, but the Hg-Sb-As anomaly shown on the map is slightly larger and includes the Snow Gulch drainage. Separate single-locality heavy-mineral-concentrate anomalies for Sn (greater than 2,000 ppm) and W (1,000 ppm) are also found in area 8 (Gray, Ryder, and Taylor, 1997). Anomalous concentrations of Hg, Sb, and As in area 8 suggest the area is favorable for the occurrence of epithermal Hg-Sb vein deposits and granite-porphyry-hosted Au-polymetallic deposits (Bundtzen and Miller, 1997).

Area 9 is at the headwaters of Moore and Bonanza Creeks near Camelback Mountain. The geology consists primarily of sedimentary rocks of the Kuskokwim Group and a small volcano-plutonic complex underlying Camelback Mountain along the northeast part of area 9. The geology is similar to that in area 2, but the area 9 anomaly is discontinuous from area 2. In or near area 9 are altered sedimentary and volcanic rock hornfels, altered monzonite, and quartz veins cutting sedimentary rocks of the Kuskokwim Group containing as much as 12 ppm Ag, 0.2 ppm Au, 710 ppm As, 5.1 ppm Hg, 70 ppm Sb, 891 ppm Cu, 35 ppm Cd, 16,800 ppm Mn, 500 ppm Pb, 600 ppm Zn, and greater than 2,000 ppm B (Bundtzen, Laird, and Lockwood, 1988; McGimsey and others, 1988). Area 9 includes 2 stream-sediment samples that contain 0.82 and 0.96 ppm Hg, 2 heavy-mineral-concentrate samples containing as much as 20 percent cinnabar, 4 stream-sediment samples containing 15-140 ppm As, and 1 moss sample that contains 2,000 ppm As. A slightly larger area that contains anomalous concentrations of Zn and W in part overlaps with area 9, but is displaced to the west (Gray, Ryder, and Taylor, 1997). Area 9 is favorable for plutonic-related B-enriched Ag-Sn-polymetallic deposits (Bundtzen and Miller, 1997) and possibly also epithermal Hg-Sb vein deposits.

An area that has predominantly Hg anomalies delineates area 10 and is near the headwaters of First Chance and Hickey Creeks. Numerous intermediate to mafic dikes intrude sedimentary rocks of the Kuskokwim Group in the vicinity of the anomaly. No mines or prospects are known from this area, but altered mafic dikes in area 10 contain as much as 2.4 ppm Hg and 14 ppm Sb (McGimsey and others, 1988). Area 10 is defined by 4 stream-sediment samples that contain 0.90-22 ppm Hg, 3 heavy-mineral-concentrate samples that contain as much as 50 percent microscopically visible cinnabar, and 1 heavy-mineral-concentrate sample containing 1,000 ppm Sb. A Au-Ag anomaly was also delineated in this area (Gray, Motooka, and O'Leary, 1997), as well as a Cu-Pb-Zn-W anomaly (Gray, Ryder, and Taylor, 1997). Anomalous concentrations of Hg and Sb in samples collected in area 10 indicate this area is favorable for the occurrence of epithermal Hg-Sb and Au-Ag vein deposits.

Area 11 is delineated by primarily Hg anomalies from samples collected on the George River, Banner Creek, and Moore Creek. This area is generally underlain by sedimentary rocks of the Kuskokwim Group, but a dacite-andesite plug and small granite porphyry dikes are also found there (Miller and Bundtzen, 1994). No mines, prospects, or mineral occurrences are known in this area; however, a sample of dacite contains 1 ppm Ag (McGimsey and others, 1988). Area 11 is defined by 6 stream-sediment samples containing 1.4 to greater than 34 ppm Hg, and 8 heavy-mineral-concentrate samples contain as much as 50 percent microscopically visible cinnabar. Approximately the western one-half of area 11 was designated by Gray, Motooka, and O'Leary (1997) as having anomalous concentrations of Au and Ag. However, the area outlined by Hg anomalies is larger, extending into additional streams east of the Au-Ag anomaly. A Cu-Zn-W anomaly overlaps with area 11 as well (Gray, Ryder, and Taylor, 1997). Cinnabar and Hg anomalies in stream-sediment and heavy-mineral-concentrate samples indicate that area 11 is favorable for epithermal Hg-Sb vein deposits.

Area 12 is underlain by sedimentary rocks of the Kuskokwim Group that are cut by granite porphyry. Sedimentary rock hornfels is found adjacent to the granite porphyry (Miller and Bundtzen, 1994). No mines, prospects, or mineral occurrences have been reported in the area. The anomaly is near the peak George (1,686 ft) where altered granite porphyry, sedimentary rock hornfels, hornfels containing quartz-stibnite veins, and vein breccia contain as much as 0.25 ppm Au, 610 ppm As, 10,000 ppm Sb, 150 ppm Cu, 1.5 ppm Cd, 200 ppm Sn, and greater than 14 ppm Hg (McGimsey and others, 1988). Area 12 is delineated by 2 stream-sediment samples that contain 1.2 and 5.0 ppm Hg; 1 of these samples contains 16 ppm As. There are no other geochemical anomalies in stream sediment, heavy-mineral-concentrate, and moss samples in area 12. Area 12 is favorable for epithermal Hg-Sb vein deposits and granite-porphyry-hosted Au-polymetallic vein deposits and the Hg and As anomalies in stream-sediment samples presented here are consistent with both deposit types.

Area 13 is on the southern boundary of the Iditarod quadrangle about 6 mi (9.6 km) southeast of Twin Buttes. In this area, dikes of mafic to intermediate composition intrude sedimentary rocks of the Kuskokwim Group. No mines are known in area 13, but the Harvison cinnabar vein prospect is about 3 mi (5 km) to the southeast in the Sleetmute quadrangle (Jasper, 1963). Although the Harvison prospect is not in area 13, the geology and geochemistry (primarily Hg) for both are comparable, suggesting that similar cinnabar vein deposits in the vicinity are possible. An altered sedimentary rock collected about 1.5 mi (2.5 km) northwest of area 13 contains 0.14 ppm Hg and 8 ppm Sb (McGimsey and others, 1988). This area is defined by 2 stream-sediment samples containing 1.6 and greater than 34 ppm Hg, and the heavy-mineral-concentrate samples collected at these 2 sites contain about 1-5 percent microscopically visible cinnabar. Area 13 is favorable for epithermal Hg-Sb vein deposits.

A small area that contains anomalous concentrations of Hg defines area 14. This area is at the headwaters of Moose Creek where sedimentary rocks of the Kuskokwim Group are intruded by granite porphyry and intermediate to mafic dikes (Miller and Bundtzen, 1994). No mines or prospects have been reported in this area, but McGimsey and others (1988) report as much as 2.3 ppm Hg in samples of oxidized sandstone of the Kuskokwim Group and altered granite porphyry. One stream-sediment sample contains 14 ppm Hg, and two heavy-mineral-concentrate samples contain as much as 50 percent cinnabar in this area. Anomalous concentrations of Hg reported here suggest that area 14 is favorable for the presence of epithermal Hg-Sb vein deposits.

The area 15 As-Sb anomaly is at the headwaters of the Dishna River and Otter Creek. In this area, sedimentary rocks of the Kuskokwim Group are intruded by granite porphyry and intermediate to mafic dikes. Mines, prospects, or mineral occurrences are not known in this area. However, vein breccias and quartz-stibnite veins are found cutting sedimentary rocks of the Kuskokwim Group and contain as much as 10,000 ppm Sb, 11 ppm Au, 1 ppm Ag, and greater than 10 ppm Hg and 10,000 ppm As (McGimsey and others, 1988). Area 15 is defined by 1 heavy-mineral-concentrate sample containing 500 ppm Sb, 2 stream-sediment samples that contain 25 and 33 ppm As, and 1 moss sample that contains 1,000 ppm As. Area 15 is favorable for epithermal Hg-Sb vein deposits and granite-porphyry-hosted Au-polymetallic deposits (Bundtzen and Miller, 1997).

The anomaly in area 16 is delineated by samples collected from tributaries on the north side of Fourth of July Creek. This small area surrounds granite porphyry that intrudes sedimentary rocks of the Kuskokwim Group. No mines, prospects, or mineral occurrences are found in this area. In area 16, 1 stream-sediment sample has 12 ppm Hg, a heavy-mineral-concentrate from the same locality contains greater than 5 percent microscopically visible cinnabar, 1 moss sample contains 150 ppm Sb, and another moss sample contains 2,000 ppm As. The area 16 Hg-Sb-As anomaly indicates the area is probably most favorable for epithermal Hg-Sb vein deposits or granite-porphyry-hosted Au-polymetallic deposits.

CONCLUSIONS

There are 16 areas identified in this study in which stream-sediment, heavy-mineral-concentrate, or aquatic-moss samples contain anomalous concentrations of Hg, Sb, or As. Anomalies for 8 of the areas (areas 1-5, 7, 8, 9) surround areas where Hg-Sb, Cu-Pb-Zn, Au-Ag vein lodes, or placer Au occurrences are known. Areas 6 and 10-16 consist of terrain where no mines, prospects, or mineral occurrences have been reported. Areas 1, 2, 4, 5, 8, and 11 are larger than those identified to have anomalous concentrations of Au and Ag (Gray, Motooka, and O'Leary, 1997). Areas 1-6 and 9-11 were also found to contain samples that have anomalous concentrations of Cu, Pb, Zn, Sn, or W (Gray, Ryder, and Taylor, 1997).

All of the 16 areas are spatially associated with Late Cretaceous and Tertiary igneous intrusions or volcanic rocks that intrude or overlie sedimentary rocks of the Late Cretaceous Kuskokwim Group. All of the areas containing anomalous concentrations of Hg, Sb, or As identified in this study are considered favorable for several types of metallic mineral deposits including epithermal Hg-Sb vein deposits, epithermal Au-Ag deposits, granite-porphyry-hosted Au-polymetallic deposits, plutonic-hosted Cu-Au-polymetallic deposits, or plutonic-related B-enriched Ag-Sn-polymetallic deposits. The data presented here suggest that during regional reconnaissance studies in southwestern Alaska, Hg concentrations greater than 0.8 ppm in stream sediments, and microscopically visible cinnabar greater than about 1 percent in nonmagnetic heavy-mineral-concentrate samples, are useful for identifying areas favorable for the occurrence of epithermal Hg-Sb deposits.

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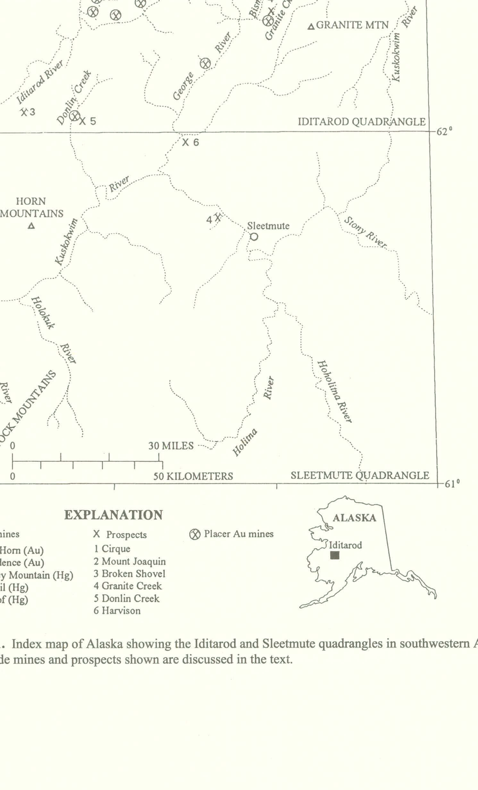

Figure 1. Index map of Alaska showing the Iditarod and Sleetmute quadrangles in southwestern Alaska. Lode mines and prospects shown are discussed in the text.

MAP SHOWING THE DISTRIBUTION OF ANOMALOUS CONCENTRATIONS OF MERCURY, ANTIMONY, AND ARSENIC IN STREAM SEDIMENT, HEAVY-MINERAL CONCENTRATE, AND AQUATIC MOSS IN THE IDITAROD QUADRANGLE, ALASKA

By

John E. Gray, Peter F. Folger, and Philip L. Hageman

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