U.S DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY



MAP B. DISTRIBUTION OF MINUS-30-MESH STREAM-SEDIMENT SAMPLES CONTAINING ANOMALOUS CONCENTRATIONS OF Ag, Au, Cd, Cu, Pb, AND Zn

Cretaceous **PENNSYLVANIAN**

CORRELATION OF MAP UNITS

(* See description of map units for specific unit age assignments)

interbedded mudstone and shale

DESCRIPTION OF MAP UNITS

- Active alluvial deposits (Quaternary)--Flood-plain deposits, lightly vegetated in some cases; includes sand dunes in Killik and Okokmilaga River valleys Surficial deposits, undivided (Quaternary)--Colluvium, older vegetated alluvial deposits, morainal deposits, terrace deposits, lacustrine material, alluvial fans, and other surficial materials not otherwise differentiated; contains some undifferentiated Tertiary terrace
- Colville Group (Upper Cretaceous)--Poorly exposed interbedded marine sandstone and shale Nanushuk Group (Upper and Lower Cretaceous)--Dominantly gray to greenish g
- sandstone and conglomeratic sandstone, interbedded with dark gray shale and coal Torok Formation (Lower Cretaceous)--Dark-gray to black clay shale and interbedded silty shale; lower part interfingers with Fortress Mountain Formation
- Fortress Mountain Formation (Lower Cretaceous)--Dominantly greenish gray graywacke interbedded with dark-gray mudstone and shale; interfingers with Torok Formation Okpikruak Formation (Lower Cretaceous)--Dominantly greenish gray graywacke with
- Etivluk Group, undivided (Jurassic to Permian)--Black chert, limestone, shale, and orange weathering siltstone, maroon mottled mudstone, and poorly exposed gray shale; consists of the Siksikpuk Formation and Otuk Formation; as mapped, locally includes distinctive overlying Lower Cretaceous coquinoid marker bed
- Mafic igneous rocks (Triassic? to Pennsylvanian)--Dark green, fine to coarse grained basalt and diabase dikes and sills
- Chert, shale, and limestone (Jurassic to Mississippian)--Gray and black pyritic chert, greenish gray chert, silicified shale and mudstone, and limestone; consists of the mnaitchiak Chert, the Akmalik Chert and other unnamed units of Lisburne Group, and local quartzose sandstone and Kayak Shale at base
- Lisburne Group, undivided (Pennsylvanian and Mississippian)--Massive, light-gray weathering limestone and dolomite, in places with abundant black chert nodules, lenses, and beds; as mapped, in many areas includes Kayak Shale at base. Locally, divided into:

Kuna Formation (Lower or Middle Pennsylvanian to Upper Mississippian)--Interbedded

- black chert, sooty limestone, and shale Kayak Shale (Mississippian)--Dark gray to black fissile shale with yellowish brownweathering thin fossiliferous limestone beds near top; lower part contains thin interbeds of gray sandstone; gradational downward into Kanayut Conglomerate
- Kanayut Conglomerate (Lower Mississippian(?) and Upper Devonian)--Thick section of gray to brown weathering quartzitic sandstone, quartz- and chert-pebble conglomerate, and shale; dominantly delta plain deposit Noatak Sandstone, Hunt Fork Shale, and Kanayut Conglomerate (part), undivided (Upper Devonian)--Dominantly fine to medium grained sandstone and quartzite with thick interbedded dark gray to brown shale; minor red to brown shale, siltstone,
- sandstone, and conglomerate; dominantly marine Hunt Fork Shale and Beaucoup Formation, undivided (Upper Devonian)--Dark gray and olive gray shale, with interbedded quartz-chert wacke, quartzite, sandstone and minor conglomerate in upper part, dominantly phyllitic shale in lower part
- Contact--Dashed where approximately located; queried where uncertain Thrust fault--Sawteeth on upper plate, dashed where approximately located; dotted where Fault--Showing relative horizontal movement. Dashed where approximately located; dotted

EXPLANATION

where concealed; queried where uncertain

Pb (100 to 300 ppm) Pb (50 to 100 ppm) Zn (700 to 1500 ppm) Zn (200 to 700 ppm)

Sulfide mineral occurrence Area boundary delineated by minus-30-mesh stream-sediment samples containing

anomalous concentrations of one or more elements

Minus-30-mesh stream-sediment sample site

STUDIES RELATED TO AMRAP The U.S. Geological Survey (USGS) is required by the Alaska National Interest Lands Conservation Act (ANILCA, Public Law 96-487, 1980) to survey Federal Lands to determine their mineral resource potential. Results from the Alaska Mineral Resource Assessment Program (AMRAP) must be made available to the public and be submitted to the President and the Congress. This report presents an interpretation of geochemical data from minus-30-mesh stream-sediment samples collected from the southern part of the Killik River quadrangle, Alaska.

The Killik River quadrangle is located in the central part of the Brooks Range and Arctic Foothills Provinces in northern Alaska (Wahrhaftig, 1965), along the northern flank and foothills of the Endicott Mountains (fig. 1). The southern third of the quadrangle is within the Brooks Range Province, whereas the northern part of the quadrangle is within the Arctic Foothills Province, which consists of the northern and southern foothills areas. The southern part of the quadrangle is characterized by rugged mountainous terrain of the Endicott Mountains with a maximum elevation of 2,236 m (7,335 ft). North of the rangefront in the central and

northern parts of the quadrangle, the terrain is predominantly flat and swampy, with some low hills.

Braided and meandering rivers drain northward through the quadrangle into the eastward-flowing

Colville River, which eventually empties into the Arctic Ocean. The sparse vegetation includes willows, grasses, sedges, mosses, lichens, and flowering plants. Permafrost underlies the entire area. A geochemical investigation of the Killik River quadrangle was conducted by the USGS between 1981 and 1986 as part of the AMRAP program. The purpose of the survey was to define geochemical variations within the quadrangle and locate areas favorable for mineral resources. Minus-30-mesh and minus-80-mesh stream-sediment samples, nonmagnetic heavy-mineral-concentrate samples derived from the stream sediment, and rock samples were collected as part of the AMRAP study. In addition, stream- and lake-sediment data obtained during the National Uranium Resource Evaluation (NURE) program were available and utilized as part of our study (Los Alamos National Laboratory, 1982). This report is one of several reports that graphically present selected geochemical and mineralogical data in map format. In this report, we present our interpretation of the geochemistry of minus-30-mesh streamsediment samples collected from the southern part of the quadrangle. The area covered is shown on figure 2. Other reports include the geochemistry and mineralogy of nonmagnetic heavy-mineralconcentrate samples collected from the southern part of the quadrangle (Kelley and others, 1995), and geochemistry of minus-100-mesh stream- and lake-sediment samples collected during the NURE survey and minus 80-mesh stream-sediment samples collected by the USGS from the northern and western parts of the Killik River quadrangle (Kelley and Mull, 1995a). A discussion comparing the results of stream-sediment and nonmagnetic heavy-mineral-concentrate samples from the southern part of the quadrangle is included in Kelley and Kelley (1992). A comprehensive summary of available geologic, geochemical, and geophysical data and an assessment of the mineral resource potential of the entire quadrangle is included in Kelley and Mull (1995b). In this report, selected element concentrations are presented on geochemical maps. As an aid to the interpretation of the regional geochemical data, we used factor analysis to identify the dominant geochemical associations in the stream-sediment samples. By expressing the overall data in terms of the principal geochemical associations, it is possible to distinguish minor variations in element

REGIONAL GEOLOGIC SETTING The Brooks Range is an east-west-trending fold and thrust belt that extends for nearly 800 km across northern Alaska and was formed during an orogenic event that began in Late Jurassic time and culminated during mid-Cretaceous time. The northern part of the Endicott Mountains, which constitute the central Brooks Range, consists primarily of Paleozoic sedimentary rocks in a series of thrust sheets that were stacked together during the Mesozoic orogenesis. The southern foothills, located north of the Endicott Mountains, consist of a zone of intensely deformed Paleozoic and Mesozoic sedimentary rocks that are parts of several major thrust sequences known as allochthons (Mayfield and others, 1983). These allochthons were thrust from the south during the formation of the Brooks Range. Farther north in the northern foothills is the Colville basin, a depositional foredeep that is filled with over 6,000 m of deltaic sedimentary deposits of Cretaceous age derived from the range.

concentrations related to lithology from those related to mineralization.

GEOLOGY OF THE KILLIK RIVER QUADRANGLE Map A shows the generalized geology of the Killik River quadrangle. The quadrangle consists mainly of Devonian to Cretaceous sedimentary rocks and minor intrusive and extrusive mafic igneous rocks. Rocks of the mountainous southern third of the quadrangle and the southern foothills are part of the Brooks Range thrust belt. The northernmost part of the quadrangle within the northern foothills is underlain by sedimentary strata deposited in the Colville basin north of the thrust belt. The rocks of the Brooks Range thrust belt have been divided into allochthons containing distinctive assemblages of rock units that have been telescoped northward by thrusting (Mayfield and others, 1987; Mull, 1982). At least five allochthons have been delineated in the quadrangle (Mull and others, 1987; Mull and

The southern third of the quadrangle consists of unmetamorphosed to weakly metamorphosed

sedimentary rocks of the Endicott Mountains allochthon (structurally the lowest of the allochthons in

the central Brooks Range) (Brosgé and others, 1979; Mull and others, 1994). In the Killik River

A few minus-30-mesh stream-sediment samples collected from tributaries south of Grizzly Mountain and from tributaries of Kugukpak and Sulugiak Creeks (Tps. 32 through 33 N., Rs. 24 200-700 ppm Zn (maps B and C); corresponding nonmagnetic heavy-mineral-concentrate samples

Sb (3 to 10 ppm)

Ni (100 to 150 ppm)

Area boundary delineated by minus-30-mesh stream-sediment samples containing anomalous concentrations of one or more elements

Minus-30-mesh stream-sediment sample site

Sulfide mineral occurrence

quadrangle, this allochthon consists of sedimentary rocks ranging from Late Devonian to Early Cretaceous age. At the base of the allochthon is the Hunt Fork Shale of Late Devonian age, which consists of a dark-gray and olive shale member interbedded with brown-weathering calcareous siltstone and fine-grained sandstone, and an overlying gray-green wacke member consisting of gray-green wacke interbedded with shale, siltstone, and sandstone. Both members represent deposition in a marine environment (Brosgé and others, 1979).

Strata of the Hunt Fork Shale are overlain by the marine Upper Devonian Noatak Sandstone, which in the Killik River quadrangle consists of light-gray to brown, fine to coarse sandstone and quartzite interbedded with dark-gray to brown shale containing ironstone nodules (Nilsen and Moore, 1984). The Noatak Sandstone is volumetrically subordinate to the underlying Hunt Fork Shale and the overlying Kanayut Conglomerate. The Kanayut Conglomerate is a Late Devonian and Early Mississippian(?) nonmarine sequence (Nilsen and Moore, 1984). It is as much as 2,600 m thick and extends east to west for more than 800 km across the Brooks Range. Sedimentary features indicate that deposition of the Kanayut Conglomerate occurred in a deltaic environment with chert-rich source areas located to the north and northeast (Nilsen and others, 1981). In the type section east of the Killik River quadrangle, the Kanayut Conglomerate contains a coarse middle part consisting predominantly of interbedded conglomerate and sandstone, and upper and lower parts consisting predominantly of sandstone, siltstone and shale. However, the conglomerate beds become progressively thinner to the west and contain smaller clasts than those present in the type section, so that conglomerate is only a minor part of the formation in the western part of the quadrangle.

The sedimentary section of Hunt Fork Shale to Kanayut Conglomerate represents a southward- or southwestward-prograding deltaic complex; the fine-grained prodelta shale beds of the Hunt Fork Shale grade upward into the wacke member of the Hunt Fork Shale and into the marine sandstone of the Noatak Sandstone, and eventually into the coarse delta-plain deposits of the Kanayut Conglomerate (Nilsen and Moore, 1984). The Kanayut Conglomerate, therefore, forms the fluvial part of the delta that prograded to the southwest during the Late Devonian and retreated during the Late Devonian and Early Mississippian(?) (Nilsen and others, 1981). Overlying the Kanayut Conglomerate are fossiliferous marine strata of the Lower Mississippian

Kayak Shale that consist dominantly of shale, with lesser amounts of siltstone, and shaly sandstone near its base, and interbedded argillaceous and ferruginous limestone near its top (Brosgé and others, 1979). Platform carbonate rocks of the Mississippian and Pennsylvanian Lisburne Group (Patton and Tailleur, 1964; Mull and others, 1982) overlie the Kayak Shale and consist primarily of medium- to light-gray limestone and dolomite with an interval of sooty black phosphatic shale and limestone near the top. Along the mountain front in the eastern part of the quadrangle, carbonate rocks of the undivided Lisburne Group are more than 300 m thick, but the unit thins westward and apparently grades into about 50 m of black chert, sooty limestone, and shale of the Kuna Formation of the Lisburne Group in the western part of the quadrangle. The Kuna Formation formed in a euxinic basin in an epicontinental setting (Mull and others, 1982).

Permian Siksikpuk Formation and the Triassic and Jurassic Otuk Formation (Mull and others, 1982). The Siksikpuk and Otuk Formations are combined as unit JPe on map A. The Siksikpuk Formation consists of about 100 m of pyritic siltstone, greenish-gray to maroon mottled mudstone and siltstone, greenish-gray silicified mudstone or chert, and an upper gray shale horizon. The greenish-gray to maroon siltstone and mudstone characteristically contain white barite lenses and nodules (Siok, 1985). The overlying Otuk Formation is also about 100 m thick and consists of a basal interval of black shale that grades upward successively into black silicified limestone and then into thinly interbedded light-gray to black banded siliceous limestone and shale containing abundant pelecypod fossils (Mull and others, 1982). Locally, a thin (less than 3m) but distinctive marker interval of Early Cretaceous coquinoid limestone overlies the Otuk Formation and marks the stratigraphic top of the Endicott Mountains allochthon. This marker interval is too thin to be differentiated in the Killik River

Disconformably overlying the Lisburne Group are rocks of the Etivluk Group, which consist of the

North of the range front is a belt of complexly deformed rocks composed of at least four allochthons that structurally overlie the Endicott Mountains allochthon (Mull and others, 1987). The stratigraphy of this belt differs markedly from that of the Endicott Mountains allochthon to the south, although there are common characteristics that suggest that all of the allochthons represent parts of a formerly continuous sedimentary basin. These allochthons consist primarily of relatively thin Upper Mississippian and Lower Pennsylvanian black pyritic chert and limestone of the Akmalik Chert of the Lisburne Group, and overlying greenish-gray chert and green and maroon siliceous shale of the Pennsylvanian to Jurassic Imnaitchiak Chert (Mull and others, 1987; Mull and others, 1994). Locally, these siliceous rocks and limestone are underlain by a thin interval of the Mississippian Kayak Shale and Mississippian quartzose sandstone that was deposited as a turbidite. The Imnaitchiak Chert, Akmalik Chert, and local basal units are combined as unit JMc on map A. Rocks within this unit locally overlie the Upper Devonian Hunt Fork Shale. The allocathons in the deformed foothills belt also contain the Lower Cretaceous Okpikruak Formation. This formation consists dominantly of greenish-gray graywacke with interbedded mudstone and shale, but local massive boulder conglomerate and chaotic debris-flow deposits are also present. These Lower Cretaceous rocks represent the oldest detritus derived from uplift of the Brooks Range.

Mafic igneous rocks intrude some of the allochthonous siliceous rocks and limestone of the deformed belt in the Otuk and Iteriak Creek area in the western part of the quadrangle. In addition, pillow basalt and other extrusive igneous rocks are present in the Kikiktat Mountain and Itkilikruich Ridges area in the central part of the quadrangle and at one locality near the western edge of the quadrangle. The extrusive igneous rocks are part of probably one of the structurally highest allochthons in the Brooks Range and are an erosional remnant of oceanic crust transported from the south and emplaced during the formation of the range.

The complexly deformed rocks of the Endicott Mountains and overlying allochthons are regionally overlain by gently folded conglomerate and graywacke of the Lower Cretaceous Fortress Mountain Formation. These proximal coarse-grained beds were derived from the Brooks Range and interfinger laterally with more complexly folded gray to black shale of the Lower Cretaceous Torok Formation (Detterman and others, 1963). The northernmost third of the quadrangle within the northern foothills is part of the Colville Basin and contains gently deformed clastic rocks of the Lower and Upper Cretaceous (Albian and Cenomanian) Nanushuk Group (Detterman and others, 1963; Huffman, 1989). The Nanushuk Group is 68°00 (Labeled and Company). a deltaic clastic wedge composed of interbedded conglomerate, sandstone, coal, and shale. It is composed of sediments derived primarily from pre-existing sedimentary rocks with a variable

contribution from mafic and ultramafic rocks, as well as metamorphic rocks and volcanic detritus (Huffman, 1985). Transport directions determined from the nonmarine facies of the delta, as well as studies of sandstone percentage and modal grain-size distribution indicate that, in the Killik River quadrangle, the delta prograded generally northward from the Endicott Mountains (Huffman, 1989). This clastic wedge was folded into a series of broad, long, linear, east-west-trending synclines and more tightly folded anticlines. Poorly exposed interbedded marine sandstone and shale of the Upper Cretaceous Colville Group (Detterman and others, 1963) overlie Nanushuk Group rocks in the northeast corner of the quadrangle, and Quaternary surficial deposits cover most of the central and northern parts of the quadrangle.

A total of 271 stream-sediment samples were collected from the southern part of the quadrangle and analyzed for this study. Sample sites were selected on first- and second-order drainages as shown on 1:63,360-scale topographic maps (or on 1:250,000-scale topographic maps in areas where the larger scale maps were nonexistent). Several grab samples were collected along 25 ft of active alluvium and composited into a single sample. Each bulk sample was passed through a 2.0-mm (10-mesh) screen to

remove coarse material. In the laboratory, the samples were sieved to minus-30 mesh and then pulverized. Each sample was analyzed for 31 elements using a direct-current arc emission spectrographic method (Grimes and Marranzino, 1968). The semiquantitative spectrographic results are reported as one of six steps (1, 0.7, 0.5, 0.3, 0.2, 0.15, and multiples of these numbers) and the values are the approximate midpoints of the concentration ranges. The precision of the analytical method is approximately plus or minus one reporting interval at the 83-percent confidence level and plus or minus two reporting intervals at the 96percent confidence level (Motooka and Grimes, 1976). The samples were also analyzed for As, Au, Cd, Sb, and Zn by atomic absorption spectrometry (Thompson and others, 1968; Viets and others, 1984). The limits of determination for both analytical methods are shown on table 1. A complete listing of the geochemical data generated by emission spectrographic and atomic absorption analyses is given in Barton and others (1982) and Sutley and others (1984). In 1989, the stream-sediment samples were resubmitted for analyses by an inductively coupled plasma-atomic emission spectroscopy method (Church, 1981); these data are tabulated by Motooka and others (1989) but were not used in the interpretation presented in this report.

STATISTICAL SUMMARY A univariate statistical summary of the stream-sediment data generated by emission spectrography and atomic absorption spectrometry is included in table 2. Qualified values are those not detected (N) or less than the lower limit of detection (L) and those greater than the upper limit of detection (G). The detection ratio (DR) is the number of samples with unqualified values divided by the total number of samples analyzed. For instance, a detection ratio of 1.0 indicates that all samples contain unqualified values for a particular element; these elements are considered "uncensored". Conversely, a detection ratio of 0.10 indicates that only 10 percent of the samples contain unqualified values of a given element; these are "highly censored" elements. In addition to the range in concentrations of all elements, the geometric mean and deviation, and the 50th, 80th, and 90th percentiles were calculated for elements with detection ratios of 0.30 or greater (i.e., the relatively uncensored elements). Prior to any calculations, values qualified with "N" were set equal to 0.5 times the lower limit of detection; those qualified with "L" were set equal to 0.7 times the lower limit of detection; those with "G" were

set equal to 1.5 times the upper limit of detection. Frequency distribution diagrams, or histograms, were constructed for the relatively uncensored elements (fig. 3). The histograms conveniently show the general distribution and ranges of the data. The boundary between the background concentration and geochemical anomaly (threshold value) of a given element was chosen by evaluation of the histograms and spatial distribution of the data, and by comparison of the sediment data with (a) worldwide average abundances of chert, shale, and limestone obtained from the literature (table 3), and (b) rock geochemical data that we collected for background information (table 4). For most elements, this threshold value corresponds approximately to the 90th percentile or greater (table 2). For highly censored elements such as silver and gold, threshold values were chosen to be the lower limit of detection (table 2). The twelve elements represented on the geochemical maps (maps B through D) are Ag, As, Au, Ba, Cd, Co, Cu, Mn, Ni, Pb, Sb, and Zn.

collected from the southern part of the quadrangle. Results of nonmagnetic heavy-mineral-concentrate samples are reported in Kelley and others (1995), and a discussion comparing the results of the two sample media are given in Kelley and Kelley (1992). Three areas in the southern part of the Killik River quadrangle are delineated by minus-30-mesh stream-sediment samples containing anomalous concentrations of Ag, As, Au, Ba, Cd, Co, Cu, Mn, Ni, Pb, Sb, and(or) Zn: (1) the Grizzly Mountain area including the tributaries of Kugukpak and Sulugiak Creeks (Tps. 32 through 33 N., Rs. 24 through 25 E.), (2) the headwaters of Outwash and Itilyiargiok Creeks (Tps. 32 through 33 N., Rs. 16 through 17 E.), and (3) three isolated areas termed the "rangefront areas" that are located along the rangefront from Otuk Creek to Kikiktat Mountain (maps B

DISCUSSION OF GEOCHEMICAL DATA

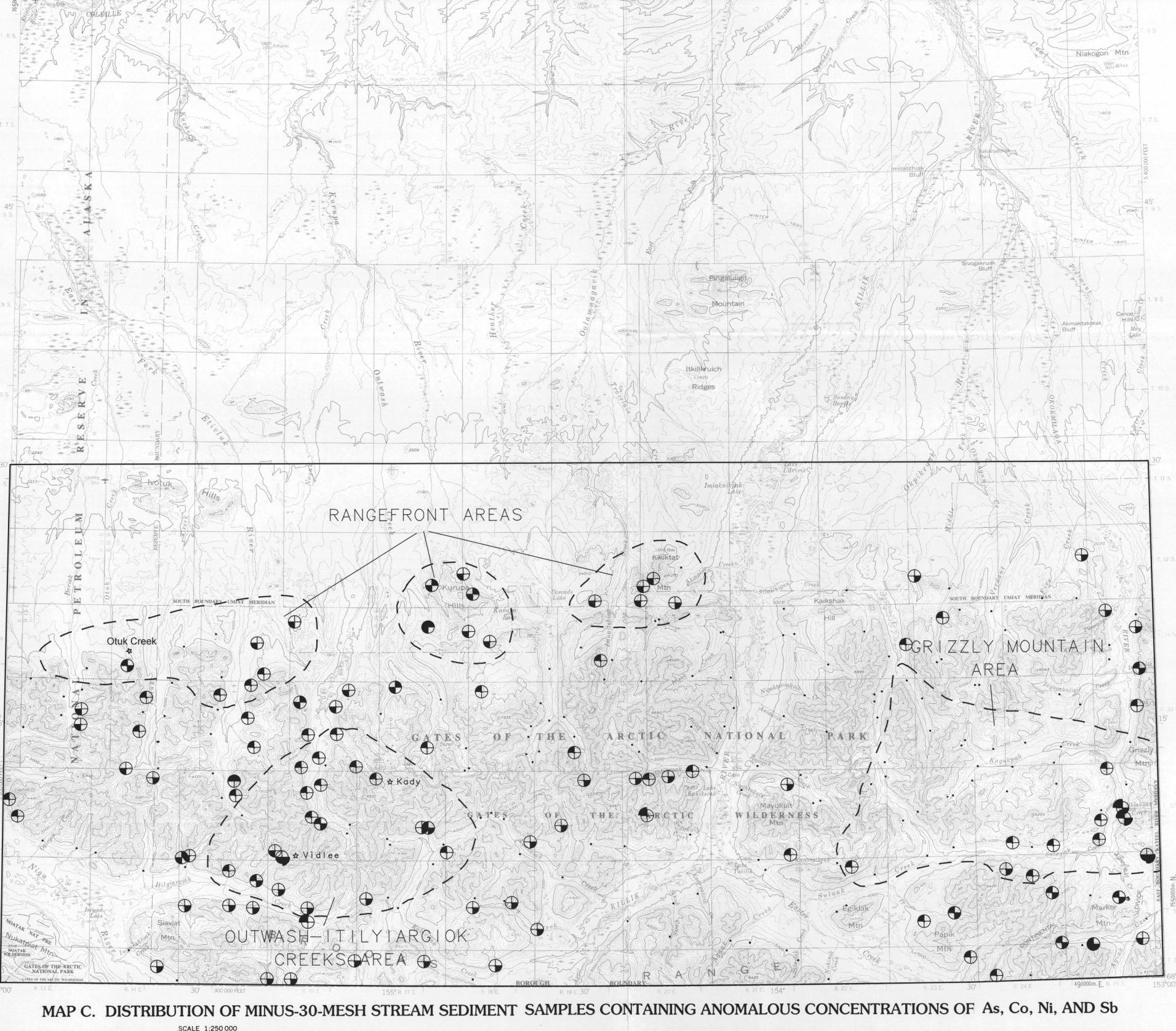
This report presents results of geochemical analyses of minus-30-mesh stream-sediment samples

through D). As an aid to the interpretation of the regional geochemical data from the southern Killik River quadrangle, we used R-mode factor analysis with varimax rotation on log-transformed minus-30-mesh stream-sediment data to define the dominant geochemical associations. This type of factor analysis groups the elements that tend to behave similarly into multielement associations, or factors (Davis, 1973, p. 500). In this way, a large number of variables is reduced to only a few variables that best characterize the original data. The factors produced from R-mode factor analysis reflect geological and geochemical processes. Twenty selected elements were included in the factor analysis. We selected a five-factor model (table 5) based on factor-variance diagrams. This five-factor model, explaining 68 percent of the variance within the original data set, is the most meaningful solution for the reconnaissance geochemical data. Factor loadings represent the contribution of each element to each factor. Factor scores measure the "effect" of a factor on each individual sample. By expressing the data in terms of these five factors, it is possible to distinguish between the trace-element variability related to lithology and that related to mineralization.

Factors 1, 2, and 5 (table 5) account for about 54 percent of the total data variability and represent lithogeochemical associations. Elements that load strongly onto factor 1 include Fe, Ti, Mn, B, Co, Cr, Cu, V, and Zr. Stream-sediment samples that yield high factor 1 scores were collected from drainage basins underlain primarily by the Noatak Sandstone and the Kanayut Conglomerate. The high factor 1 scores probably represent sphene, zircon, rutile, and other detrital minerals contained in the sandstone and conglomerate. Factor 2 (Mg-Ca-La) represents carbonate rocks. Samples with high scores for this factor are

spatially associated with carbonate rocks of the Pennsylvanian and Mississippian Lisburne Group. High scores for factor 5 (Fe-B-Co-Cr-La-Ni-Pb-Sc-Sr-V-Y) occur in samples that are widely distributed and show no consistent correlation with any particular rock unit. This factor probably represents shale, which is common throughout the southern Killik River quadrangle. Factors 3 and 4 represent mineralization suites. The Ca-Ba-Mn-Sr association (factor 3) indicates the abundance of barite, which is commonly present as veins and lenses in the rocks of the Etivluk Group, particularly the Permian Siksikpuk Formation. Samples with high factor 3 scores also contain high concentrations of Ba (1,000->5,000 ppm) and Mn (2,000->5,000 ppm) (map D). Factor 4 (As-Cu-Mn-Pb-Zn) is indicative of base-metal mineralization. The distribution of samples with high factor 4 scores is shown on map E. Although a few of the samples that contain high scores were collected from the eastern part of the quadrangle near Grizzly Mountain, most samples were collected from tributaries of Outwash and Itilyiargiok Creeks or along the rangefront in the west-central part of the quadrangle.

GRIZZLY MOUNTAIN AREA hrough 25 E.) contain 15-50 ppm As, 1-3 ppm Cd, 70 ppm Cu, 50-100 ppm Pb, 1-10 ppm Sb, and



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contain highly anomalous concentrations of these elements, and pyrite, chalcopyrite, galena, and sphalerite were also observed in many of these samples (Kelley and others, 1995). The dominant lithologies in the area are the Hunt Fork Shale and the Kanayut Conglomerate. Geochemical data obtained from rock samples collected from the Grizzly Mountain area are listed in table 4. Most of the samples were collected from float in the stream drainages; the majority of the samples are quartz veins hosted by the Hunt Fork Shale, but three are samples of the Kanayut Conglomerate containing disseminated pyrite which, in most cases, is highly oxidized. Three of the quartz vein samples contain 10 percent Fe and 130-200 ppm Zn; pyrite was found in two of the vein samples, and sphalerite was noted in one vein sample. Most of the sulfide-bearing veins in the Grizzly Mountain area are thin (1-2 cm) discontinuous veins that probably formed during compaction and diagenesis of the Hunt Fork Shale (Duttweiler, 1987). Three samples of disseminated pyrite in conglomerate and sandstone of the Kanayut Conglomerate were also collected and analyzed. Except for minor enrichments of Ag (1.0-1.9 ppm), these samples contain background concentrations of most elements (table 4).

OUTWASH-ITILYIARGIOK CREEKS AREA Many samples collected from the western part of the quadrangle at the headwaters of Outwash and Itilyiargiok Creeks (Tps. 32 through 33 N., Rs. 16 through 17 E.) contain anomalous concentrations of Ag (as much as 1 ppm), Cu (70-100 ppm), Pb (50-300 ppm), and Zn (200-1,500 ppm) (map B). In addition, arsenic contents range from 15 to 50 ppm and antimony concentrations of 1 to 10 ppm are widespread (map C). Two samples collected from tributaries of Itilyiargiok Creek contain detectable Au (0.05-0.1 ppm) (map B). Nonmagnetic heavy-mineral-concentrate samples contain abundant visible

galena and sphalerite as well as corresponding anomalous concentrations of base metals (Kelley and The stream-sediment samples collected from the tributaries of Outwash and Itilyiargiok Creeks also vielded high factor 4 (As-Cu-Mn-Pb-Zn) scores (map E). Further field investigation of the geochemical anomalies in this area revealed two localities of highly mineralized vein systems (Duttweiler, 1987). The northernmost area, informally named the Kady occurrence, is located at the headwaters of a tributary of Outwash Creek; the other vein system, the Vidlee occurrence, is located along a tributary to

At the Kady occurrence, disseminated, massive, and quartz vein-hosted sulfides are present in Upper Devonian sandstone and conglomerate of the Kanayut Conglomerate. The predominant sulfide minerals are sphalerite and pyrite, although galena and chalcopyrite are also present. Sulfide-bearing quartz veins and vein breccias crop out at several localities along the 3.5-km length of the east-west trending stream (T. 32 N., R. 17 E.). The veins, which strike north to slightly northwest, range from 2cm-wide stockwork veinlets to massive veins nearly 2.5 m wide. In addition, boulders and small cobbles of massive and brecciated sulfides are found at the surface in frost boils and colluvium. In addition to the Kady occurrence, numerous mineralized veins occurrences were found either as float or outcrop in tributaries of Outwash Creek to the northeast and southwest of the Kady occurrence (Meyer and Kurtak, 1992).

Mineralized rocks collected from the Vidlee occurrence are primarily sulfide-bearing veins and

breccias hosted by shale and shaly siltstone of the Upper Devonian Hunt Fork(?) Shale. Galena, pyrite, and sphalerite are the predominant minerals. The mineralized outcrop is exposed at stream level over a horizontal distance of about 25 m. It cannot be traced either horizontally or vertically from this exposure due to tundra cover. Individual sulfide-bearing veins range from 1.5 cm to as much as 1.5 m in width, and strike nearly due north. Much of the mineralized material consists of breccias with clasts of shale and sandstone rimmed with quartz and containing sulfide minerals in the interstices. The results of geochemical analyses of rock samples collected from these areas are listed in table 4. Mineralized rocks of the Kady occurrence contain as much as 150 ppm Ag, 500-1,000 ppm As, 780-1,900 ppm Cd, 1,500 to more than 20,000 ppm Cu, 500-700 ppm Pb, and as much as 21 percent (210,000 ppm) Zn. Mineralized rocks of the Vidlee area contain highly anomalous concentrations of Ag (150-300 ppm), As (as much as 6,400 ppm), Au (0.05-0.75 ppm), Cd (2,500-2,800 ppm), Cu (1,500-10,000 ppm), Pb (1,000 to more than 20,000 ppm), Sb (as much as 2,000 ppm), and Zn (14-25 percent). In addition to the anomalous concentrations of these elements, a few rocks contain high concentrations of cobalt and nickel, which reflects the abundance of pyrite in the veins, and several contain 200-300 ppm Sn (not shown on table 4).

RANGEFRONT AREAS Minus-30-mesh stream-sediment samples collected along the rangefront between Otuk Creek and Kikiktat Mountain contain high concentrations of Ba (1,000 to more than 5,000 ppm) and Mn (2,000 to more than 5,000 ppm) (map D). Many of these samples also contain anomalous concentrations of As, Cd, Co, Ni, Pb, or Zn (maps B and C). The corresponding nonmagnetic heavy-mineral-concentrate samples collected from the same sites contain greater than 50 percent barite, abundant pyrite, and trace amounts of other sulfide minerals (Kelley and others, 1995). The source of the barite is most likely barite nodules, lenses, and veins in the Siksikpuk Formation of the Etivluk Group (Siok, 1985) that crops out along the rangefront from Otuk Creek to Kikiktat Mountain. Pyrite is present in two formations of the Etivluk Group: the lowermost part of the Siksikpuk Formation contains large euhedral crystals and finely disseminated framboids (Siok, 1985); the Otuk Formation consists, in part, of a black pyritic shale interval (Bodnar, 1984). Shale and chert of the Kayak Shale (Mk) and Kuna Formation (IPMk) are also exposed along the rangefront and are additional possible sources of barium and base metals in the minus-30-mesh stream-sediment samples. Based on the geochemical anomalies in minus-30-mesh stream-sediment samples, detailed

geochemical studies conducted along the rangefront focused on three areas: (1) Otuk Creek in the western part of the quadrangle, (2) Kurupa Hills, and (3) Kikiktat Mountain. Sulfide-bearing concretions hosted by the Lower Mississippian Kayak Shale were found to be abundant in one outcrop located at the headwaters of Otuk Creek. The concretions range from 7.6 to 20 cm in diameter. They contain abundant calcite and minor amounts of sulfide minerals, including red-brown sphalerite, galena, chalcopyrite, and pyrite. Geochemical analyses of the concretions are listed in table 4 (samples AKD625B and AKD625C). In addition to anomalous concentrations of Fe (20 percent), the samples contain elevated concentrations of Ag (0.8-2.3 ppm), Ba (more than 5,000 ppm), Mn (3,000 ppm), and Zn (300-1,500 ppm). Although sulfide-bearing concretions such as these were not found in the Kayak Shale elsewhere in the quadrangle, they were found in the Howard Pass quadrangle to the west (K.D. Kelley, unpub. data, 1990) and the Chandler Lake quadrangle to the east (J.M. Kurtak, oral communication, 1994). This indicates they may be fairly common in the Kayak Shale, and may be a source of anomalous concentrations of base metals in minus-30-mesh streamsediment samples collected elsewhere along the rangefront. Sooty black shale of the Kuna Formation hosts the Red Dog stratiform silver-barium-lead-zinc deposit in the western Brooks Range (Moore and others, 1986). The Kuna Formation is exposed in a few of the basins containing geochemical anomalies between Otuk Creek and the Kurupa Hills. Although no sulfide minerals were found, one chert sample of the Kuna Formation from Otuk Creek contains 200 ppm Zn, 700 ppm Ba, and 3 ppm Ag (sample AKD625F; table 4), which are high relative to average worldwide abundances of these elements in chert (table 3), or compared to other chert samples from the Killik River quadrangle (table In the Kurupa Hills area (T. 12 S., Rs. 17 E. and 18 E.), a few minus-30-mesh stream-sediment samples contain anomalous concentrations of Ba, Co, Ni, Pb, and (or) Zn (maps B through D), and

abundant barite and minor pyrite were found in nonmagnetic heavy-mineral-concentrate samples (Kelley

and others, 1995). Chip samples were collected through the Mississippian to Triassic chert and shale

samples contain elemental concentrations similar to those of average chert and shale (table 3)

sequence. Except for one pyritic chert sample that contains 500 ppm Ni (sample AKD079; table 4), the

At Kikiktat Mountain (T. 12 S., R. 20 E.), a few minus-30-mesh stream-sediment samples contain anomalous concentrations of barium, copper, nickel, or zinc; however, most samples contain only single-element anomalies rather than multielement anomalies that are common for areas discussed previously. Chert and mafic igneous rocks at Kikiktat Mountain contain local disseminated pyrite and chalcopyrite. Background trace element concentrations of the mafic rocks are as follows: 3-5 percent Fe, 20-50 ppm Co, 150-500 ppm Cr, 100 ppm Cu, and 50-100 ppm Ni. Chert samples contain mostly 500-3,000 ppm Ba, 10-30 ppm Cu, 10-20 ppm Cr, 10 ppm Co, and 0.5-1 ppm Ag (table 4). Except for the local accumulation of pyrite and minor chalcopyrite in the chert and mafic igneous rocks, and barite in shale and chert that surrounds Kikiktat Mountain, the rocks of this area do not appear to be

Three areas in the southern part of the Killik River quadrangle are characterized by minus-30-mesh stream-sediment samples containing anomalous concentrations of one or more elements including Ag, As, Au, Ba, Cd, Co, Cu, Mn, Ni, Pb, Sb, and(or) Zn. The Grizzly Mountain area in the eastern part of the Killik River quadrangle is characterized by anomalous concentrations of As, Cu, Pb, Sb, and Zn in a few widely scattered minus-30-mesh stream-sediment samples; quartz-carbonate veins containing minor amounts of sulfide minerals were the only source identified. These veins, which are hosted primarily by the Hunt Fork Shale, are thin, discontinuous veins that appear to have formed during low-grade metamorphism. Although the minus-30-mesh stream-sediment data suggest that mineralization in the Grizzly Mountain area may have been minimal, the presence of abundant pyrite, chalcopyrite, galena, and sphalerite, with corresponding highly anomalous concentrations of base metals

exists (Kelley and Kelley, 1992; Kelley and others, 1995).

Relative to the Grizzly Mountain area, the Outwash and Itilyiargiok Creeks area in the western part of the quadrangle is characterized by numerous minus-30-mesh stream-sediment samples containing highly anomalous concentrations of silver, copper, lead, and zinc (as well as arsenic and antimony, with or without gold). Follow-up geochemical studies in this area resulted in the discovery of two mineralized vein systems, informally named the Kady and Vidlee occurrences. Both are hosted by Devonian clastic rocks. In addition to silver, copper, lead, and zinc, mineralized rocks contain anomalous concentrations of arsenic, gold, antimony, and minor tin. Along the rangefront, minus-30-mesh sediment samples contain anomalous concentrations of Ba with or without As, Cd, Co, Mn, Ni, Pb, or Zn. Abundant barite and pyrite, and trace amounts of other

sulfide minerals were observed in nonmagnetic heavy-mineral-concentrate samples (Kelley and others, 1995). Rocks of the Etivluk Group, particularly the Siksikpuk Formation, are probably the source of much of the barite and pyrite. Other possible sources of anomalous concentrations of barium and base metals in minus-30-mesh stream-sediment samples collected from the headwaters of Otuk Creek and east along the rangefront to the Kurupa Hills are the Kayak Shale and Kuna Formation. Sulfide-bearing concretions were found in the Kayak Shale at one locality along Otuk Creek; although no sulfide minerals were observed in the Kuna Formation, silver and zinc concentrations in one chert sample from Otuk Creek are high relative to worldwide average abundances in chert. Finally, igneous rocks containing pyrite and minor chalcopyrite, and shale and chert containing barite and pyrite were found at Kikiktat Mountain; these are the most likely source rocks for anomalous concentrations of barium and other metals in samples collected from this area.

Adachi, Mamoru, Yamamoto, Koshi, and Sugisaki, Ryuichi, 1986, Hydrothermal chert and associated siliceous rocks from the northern Pacific: their geological significance as indication of ocean ridge activity: Sedimentary Geology, v. 47, p. 125-148. Barton, H.N., Odland, S.K., O'Leary, R.M., and Day, G.W., 1982, Geochemical data for the Killik River and Chandler Lake quadrangles, Alaska: U.S. Geological Survey Open-File Report 82-1026, Bodnar, D.A., 1984, Stratigraphy, age, depositional environments, and hydrocarbon source rock evaluation of the Otuk Formation, north-central Brooks Range: Fairbanks, University of Alaska,

M.S. thesis, 232 p. Brosgé, W.P., Reiser, H.N., Dutro, J.T., Jr., and Nilsen, T.H., 1979, Geologic map of Devonian rocks in parts of the Chandler Lake and Killik River quadrangles, Alaska: U.S. Geological Survey Open-File Report 79-1224, scale 1:200,000. Church, S.E., 1981, Multiple element determinations in geological reference samples--an evaluation of the inductively coupled plasma-atomic emission spectroscopy method for geochemical applications,

in Barnes, R.M., ed., Developments in atomic plasma spectrochemical analysis, Hayden and Sons, Philadelphia, Pennsylvania, p. 410-434. Davis, J.C., 1973, Statistics and data analysis in geology: John Wiley & Sons, Inc., New York, 550 p. Detterman, R.L., Bickel, R.S., and Gryc, George, 1963, Geology of the Chandler River region, Alaska--Exploration of Naval Petroleum Reserve No. 4 and adjacent areas, Northern Alaska, 1944-53, Part 3, Areal geology: U.S. Geological Survey Alaska--Accomplishments during 1985: U.S. Geological Survey Professional Paper 303-E, p. 233-324. Duttweiler, K.A., 1987, Use of factor analysis in locating base metal mineralization in the Killik River quadrangle, Alaska, in Hamilton, T.D., and Galloway, J.P., eds., Geologic studies in Alaska by the

U. S. Geological Survey during 1986: U. S. Geological Survey Circular 998, p. 27-30. Grimes, D.J., and Marranzino, A.P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p. Huffman, A.C., Jr., 1985, Introduction, in Huffman, A.C., Jr., ed., Geology of the Nanushuk Group and related rocks, North Slope, Alaska: U.S. Geological Survey Bulletin 1614, p. 1-6. Huffman, A.C., Jr., 1989, The Nanushuk Group, in Mull, C.G., and Adams, K.E., eds., Dalton

Highway, Yukon River to Prudhoe Bay, Alaska; Bedrock geology of the eastern Koyukuk basin, central Brooks Range and east central Arctic Slope, Guidebook: Alaska Division of Geological and Geophysical Surveys Report no. 7, v.2, p. 303-309. Kelley, K.D., and Kelley, D.L., 1992, Reconnaissance exploration geochemistry in the central Brooks Range, northern Alaska: Implications of exploration of sediment-hosted zinc-lead-silver deposits: Journal of Geochemical Exploration, v. 42, p. 273-300. Kelley, K.D., and Mull, C.G., 1995a, Maps showing the distribution of selected elements in minus-100-mesh and minus-80-mesh sediment samples from the Killik River quadrangle: U.S.

Geological Survey Miscellaneous Field Studies Map MF-2225-B, scale 1:250,000. Kelley, K.D., and Mull, C.G., 1995b, Maps showing areas of potential for mineral resources in the Killik River quadrangle, Brooks Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2225-A, scale 1:250,000. Kelley, K.D., Mull, C. G., and Barton, H. N., 1995, Maps showing the distribution of selected elements and mineralogy of nonmagnetic heavy-mineral concentrate samples from the southern part of the Killik River quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map

Los Alamos National Laboratory, 1982, Uranium hydrogeochemical and stream-sediment

Levinson, A.A., 1974, Introduction to exploration geochemistry: Applied Publications, Ltd., Calgary

reconnaissance of the Killik River quadrangle, Alaska: U.S. Department of Energy Report GJBX

MF-2225-D, scale 1:250,000.

Alberta, 612 p.

37(82), 80 p.

C5, D5, D6, and D7 quadrangles, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map I-1814, scale 1:63,360. Mayfield, C.F., Tailleur, I.L., and Ellersieck, Inyo, 1983, Stratigraphy, structure, and palinspastic synthesis of the western Brooks Range, northwestern Alaska: U.S. Geological Survey Open-File Report OF-83-779, 58 p., scale 1:1,000,000. Maynard, J.B., 1991, Shale-hosted deposits of Pb, Zn, and Ba: Syngenetic deposition from exhaled brines in deep marine basins, in Force, E.R., Eidel, J.J., and Maynard, J.B., eds., Sedimentary and diagenetic mineral deposits: A basin analysis approach to exploration: Reviews in Economic Geology, v. 5., p. 177-183. Meyer, M.P., and Kurtak, J.M., 1992, Results of the 1991 U.S. Bureau of Mines Colville Mining District study: U.S. Bureau of Mines Open-File Report 75-92, 101 p. Moore, D.W., Young, L.E., Modene, J.S., and Plahuta, J.T., 1986, Geologic setting and genesis of the Red Dog zinc-lead-silver deposit, western Brooks Range, Alaska: Economic Geology, v. 81, no. 7, p. 1696-1727.

Mayfield, C.F., Ellersieck, Inyo, and Tailleur, I.L., 1987, Reconnaissance geologic map of the Noatak

MISCELLANEOUS FIELD STUDIES

SHEET 1 OF 2

Motooka, J.M., Adrian, B.M., Church, S.E., McDougal, C.M., and Fife, J.B., 1989, Analytical data and sample locality map for aqua-regia leachates of stream sediments analyzed by ICP, and emission spectrographic and ICP results for many NURE stream sediments from the Killik River quadrangle, Alaska: U.S. Geological Survey Open-File Report 89-12, 77 p., 2 sheets, scale Motooka, J.M., and Grimes, D.J., 1976, Analytical precision of one-sixth order semiquantitative spectrographic analyses: U.S. Geological Survey Circular 738, 25 p. Mull, C.G., 1982, The tectonic evolution and structural style of the Brooks Range, Alaska--An illustrated summary, in Powers, R.B., ed., Geological studies of the Cordilleran thrust belt: Denver, Colorado, Rocky Mountain Association of Geologists, v. 1, p. 1-45. Mull, C.G., Tailleur, I.L., Mayfield, C.F., Ellersieck, Inyo, and Curtis, S., 1982, New Upper Paleozoic and lower Mesozoic stratigraphic units, central and western Brooks Range, Alaska: American Association of Petroleum Geologists Bulletin, v. 66, no. 3, p. 348-362. Mull, C.G., Crowder, R.K., Adams, K.E., Siok, J.P., Bodnar, D.A., Harris, E.E., Alexander, R.A.,

and Solie, D.N., 1987, Stratigraphy of the Picnic Creek allochthon, Killik River quadrangle, central Brooks Range, Alaska, in Tailleur, I.L., and Weimer, Paul, eds., Alaskan North Slope geology: Society of Paleontologists and Mineralogists Field Trip Guidebook 50, p. 650-662. Mull, C.G., Moore, T.E., Harris, E.E., and Tailleur, I.L., 1994, Preliminary geologic map of the Killik River quadrangle, central Brooks Range, Alaska: U. S. Geological Survey Open-File Report 94-679, scale 1:125,000. Nilsen, T.H., Brosgé, W.P., Dutro, J.T., Jr., and Moore, T.E., 1981, Depositional model for the fluvial Upper Devonian Kanayut Conglomerate, Brooks Range, Alaska in Albert, R. D., and Hudson, Travis, eds., The United States Geological Survey in Alaska: Accomplishments during 1979: U.S. Geological Survey Circular 823-B, p. 20-21. Nilsen, T.H., and Moore, T.E., 1984, Stratigraphic nomenclature for the Upper Devonian and Lower

Mississippian(?) Kanayut Conglomerate, Brooks Range, Alaska: U.S. Geological Survey Bulletin 1529-A, 64 p. Patton, W.W., Jr., and Tailleur, I.L., 1964, Geology of the Killik-Itkillik region, Alaska: U. S. Geological Survey Professional Paper 303-G, p. 409-500. Siok, J.P., 1985, Lithostratigraphy, petrology, age, and depositional environments of the Siksikpuk Formation on the Endicott Mountains and Picnic Creek allochthons, north-central Brooks Range, Alaska: Fairbanks, University of Alaska, M. S. thesis, 235 p. Sutley, S.J., Duttweiler, K.A., and Hopkins, R.T., 1984, Analytical results and sample locality map of stream-sediment and panned-concentrate samples from the Killik River 1° x 3° quadrangle, Alaska: U.S. Geological Survey Open-File Report 84-406, 20 p. Thompson, C.E., Nakagawa, H.M., and Van Sickle, G.H., 1968, Rapid analysis for gold in geologic

600-B, p. 130-132. Viets, J.G., O'Leary, R.M., and Clark, J.C., 1984, Determination of arsenic, antimony, bismuth, cadmium, copper, lead, molybdenum, silver, and zinc in geological materials by atomic absorption spectrometry: The Analyst, v. 109, p. 1589-1592. Vine, J.D., and Tourtelot, E.B., 1970, Geochemistry of black shale deposits--a summary report: Economic Geology, v. 65, p. 253-272. Wahrhaftig, Clyde, 1965, Physiographic divisions of Alaska: U.S. Geological Survey Professional

materials, in U.S. Geological Survey Research 1968: U.S. Geological Survey Professional Paper

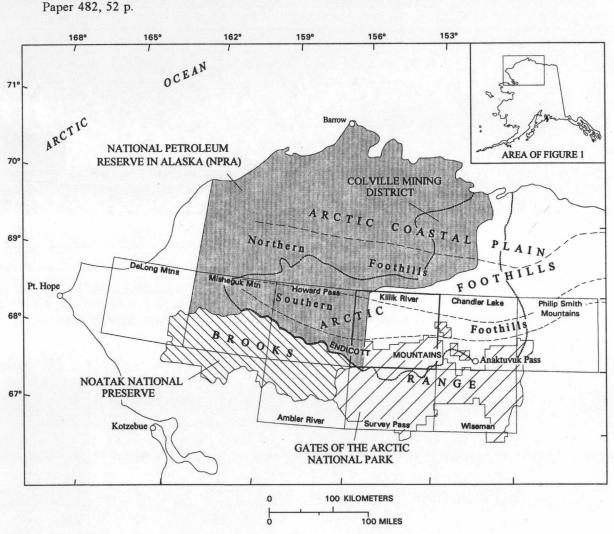


Figure 1. Location of the Killik River quadrangle, Brooks Range, Alask

MAPS SHOWING DISTRIBUTION OF SELECTED ELEMENTS IN MINUS-30-MESH STREAM SEDIMENT SAMPLES FROM THE SOUTHERN PART OF THE KILLIK RIVER $1^{\circ} \times 3^{\circ}$ QUADRANGLE, ALASKA

1995

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