data variance

< 20

N(500)

N(1) N(500)

N(10)

N(10)

N(200)

N(500)

Au, Sb, W, and Th concentrations were below the limit of determination in all samples (lower limits 20, 200, 50, and 200 ppm. respectively), and Bi concentrations were below the limit of determination in all samples from area 1 (lower limit 20 ppm)

Calculated only for elements with detection ratio of 0.3 or greater--values with "N" were set equal to one-quarter the lower

determination limit; values with "L" were set equal to one-half the lower determination limit; values with "G" were set equal

to twice the upper determination limit.

Area 2

1,000

>2,000

>2% 10,000 500 1,500

1,000

1,000

1,000

>20,000

.3% 3.8%

2.8%

4.0% 4.5% 2.8

explained by factor

ARCTIC COASTAL PLAIN PROVINCE

BROOKS RANGE PROVINCE

Chandler Lake quadrangle, Alaska.

Chandler Lake

Figure 1. Index map of the central and eastern Brooks Range showing location of the

Mountains

CL779 CL780

CL781

CL783

CL728

CL731

AKD445

AKD446 AKD447

AKD450

AKD451

AKD453 AKD454

AKD455 AKD457

AKD458

AKD460

CL770 CL771 CL773R1

CL773R3

CL773R5

CL773R6

CL773R7 CL774

CL775 CL776 CL777

Oolah Mountain

68 05 31

68 05 38

68 01 56

68 03 02

68 03 32

68 03 32

68 03 23

68 03 23

68 03 23

68 03 23

68 03 23

68 03 23

68 03 04

68 08 10

68 09 55

68 09 55

68 09 55

68 09 55

68 09 55

68 07 28

68 07 28

68 07 28

68 03 23

68 03 32

150 43 13

150 53 31

150 57 40

150 57 40

150 57 40

150 57 40

150 57 40

150 57 40

150 57 40

150 57 22

150 03 30

150 06 10

150 06 10

150 06 10

150 06 10

150 06 10

150 06 10

150 01 40

150 01 40

150 01 40

zinc analyzed by atomic absorption method; analysis for all other elements are by emission spectrographic method

150 57 40

<10

<10

<.5

CL846-CL849

<10

INDEX MAP SHOWING LOCALITIES OF ROCK SAMPLES LISTED IN TABLE 3

Calcite veins

Black shale-siltstone

k; conglomerate with pyrite concretions

Dk; conglomerate with disseminated pyrite

Ok; medium-grained sandstone with pyrite

Quartz veins; minor pyrite and sphalerite

Conglomerate with disseminated pyrite

Medium-grained sandstone with pyrite

Medium-grained sandstone with pyrite

Medium-grained sandstone with pyrite

Ok; conglomerate with disseminated pyrit

Medium-grained sandstone with pyrite

Medium-grained sandstone with veins

Shale-siltstone with oxidized pyrite

Black shale-siltstone

Red-brown shale

Silicified sandstor

Dk; sandstone

Shale-siltstone

Quartz veining

Green sandstone with pyrite

Green sandstone with pyrite

Holocene

Cretaceous

Lower

Lower

Mississippiar

Devonian

Overturned anticlin

Overturned syncline

steeper dipping limb

Thrust fault---Sawteeth on upper plate

EXPLANATION

Major folds --- Showing direction of plunge where known

Syncline---Dashed where inferred position of strata that formed

Strongly asymmetrical syncline---Double dip arrow indicates

Detachment surface---Approximately located. Sawteeth on upper plate

Shear zone---Melange; zone of pervasively sheared and structurally

Outcrops of shaly strata in undivided part (Dh) of Hunt Fork Shale

STUDIES RELATED TO AMRAP

INTRODUCTION

nmagnetic heavy-mineral-concentrate sample locality

Fault---Type uncertain; ticks indicate hanging-wall block

Outcrops of radiolarian ribbon chert and very cherty

Tectonic block of coquinoid limestone in melange

rhytmically bedded limestone

Outcrop of basalt---Locally pillowed

Well---Drilled for oil and gas; abandoned

syncline is found in upper thrust plate and since been eroded

Unconformity

Kcl

Jīkos

Ps PsI

Unconformity(?

Maw Mawc

Mk

Cretaceous

QUATERNARY

CRETACEOUS

TRIASSIC

MISSISSIPPIAN

DEVONIAN

The U.S. Geological Survey is required by the Alaskan National Interest Lands Conservation Act (ANILCA, Public Law 96-487, 1980) to survey Federal Lands to determine their mineral resource potential. Results from the Alaskan Mineral Resource Assessment Program (AMRAP) must be made available to the public and be submitted to the President and the Congress. This report presents the results of a geochemical and mineralogical study of nonmagnetic heavy-mineral-concentrate samples collected from the southern part of the Chandler Lake quadrangle, Alaska.

The Chandler Lake quadrangle is located in the central part of the Brooks Range and Arctic Foothills provinces of northern Alaska (fig. 1). A geochemical investigation of the Chandler Lake quadrangle has been underway since 1981 as part of the Alaskan Mineral Resource Assessment Program. The purpose of the survey was to define geochemical variations within the quadrangle and locate areas favorable for mineralization. Unconsolidated stream sediments, nonmagnetic heavy-mineral concentrates derived from the stream sediments, and rock samples were used for the study. Throughout this report, the nonmagnetic heavy-mineral-concentrate samples will be referred to as concentrates. This report presents an interpretation of geochemical and mineralogical data from concentrates collected from the southern part of the Chandler Lake quadrangle. It is one of a series of three reports that graphically present selected geochemical and mineralogical data in map format. Other reports in the series include an interpretation of stream-sediment geochemical data in the southern part of the Chandler Lake quadrangle (Kelley and others, 1993) and of stream- and lake-sediment data collected from the northern part of the Chandler Lake quadrangle as part of the National Uranium Resource Evaluation (NURE) program (Kelley and Sutley, 1993). A comprehensive report on the mineral resource assessment of the quadrangle is also currently underway (S.E. Church and others, written

communication, 1992). In this report, Ag, As, Co, Cu, Pb, Ni, and Zn concentrations, as well as the distribution of arsenopyrite, barite, chalcopyrite, galena, pyrite, and sphalerite in the concentrate samples are presented on geochemical and mineralogical maps. However, visual interpretation of multielement data may only serve to delineate the obvious geochemical features, leaving the more subtle geochemical signatures undetected. Therefore, as an aid to the nterpretation of the regional geochemical data, we used factor analysis to identify the dominant geochemical associations in the heavy-mineralconcentrate samples. By expressing all of the data in terms of the principal geochemical associations, it is possible to separate the minor elemental variations related to lithology from those related to mineralization. We used factor analysis only on concentrates collected from the southeastern part of the quadrangle; the number of samples collected elsewhere in the quadrangle is not sufficient for meaningful interpretation of factor analysis.

GENERALIZED GEOLOGY The southern boundary of the Chandler Lake quadrangle, which lies south of the Brooks Range continental divide, is within the Brooks Range Province of Wahrhaftig (1965) (fig. 1). The northern and southern foothills areas of the Arctic Foothills Province comprise the northern two-thirds of the

The geologic map shows the generalized geology of the Chandler Lake quadrangle (Kelley, 1990). The southern part of the quadrangle is comprised of unmetamorphosed to weakly metamorphosed sedimentary rocks that are folded and thrust-faulted (Brosgé and others, 1979). The Upper Devonian Hunt Fork Shale, as described by Brosgé and others (1979), includes two members: the wacke member consists of gray-green wacke interbedded with shale, siltstone, and sandstone, and the shale member consists of dark-gray and olive shale interbedded with brown-weathering calcareous siltstone and fine-grained sandstone. Both members represent deposition in a marine environment (Brosgé and others, 1979).

Marine strata of the Hunt Fork Shale are overlain by the marine Noatak Sandstone, which in turn is overlain by a nonmarine sequence belonging to the Upper Devonian and Lower Mississippian(?) Kanayut Conglomerate (Nilsen and Moore, 1984). The Kanayut Conglomerate is as thick as 2,600 m and extends across the Brooks Range for more than 800 km from east to west (Nilsen and Moore, 1984). The Kanayut Conglomerate contains a coarse middle part of interbedded conglomerate and sandstone, and upper and lower parts consisting of sandstone, siltstone, and shale. The conglomerate contains clasts of chert, quartz, quartzite, and argillite (Brosgé and others, 1979; Nilsen and others, 1981). Sedimentary features in the Kanayut Conglomerate indicate that deposition occurred in a deltaic environment with chert-rich source areas to the north and northeast (Nilsen and others, 1981).

The Hunt Fork Shale-Kanayut Conglomerate sequence represents a southward- or southwestward-prograding deltaic complex; the coarse deltaplain deposits of the Kanayut grade downward into the marine sandstone of the Noatak Sandstone, the wacke member of the Hunt Fork Shale, and the prodelta shales of the lower part of the Hunt Fork Shale (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,

Overlying the Kanayut Conglomerate are fossiliferous marine strata of the Lower Mississippian Kayak Shale that consist of shale, siltstone, and shaly sandstone interbedded with argillaceous and ferruginous limestone (Brosgé and others, 1979). The Mississippian Lisburne Group (Patton and Tailleur, 1964) overlies the Kayak Shale and consists primarily of medium- to light-gray limestone and dolomite with dark-gray phosphatic limestone, shaly limestone, chert, and shale.

The Permian Siksikpuk Formation disconformably overlies Lisburne Group carbonate rocks. The Siksikpuk Formation has been subdivided into four lithostratigraphic subunits (Siok, 1985); the subunits consist of a lower gray to greenish-gray pyritic siltstone, greenish-gray to maroon mottled mudstone and siltstone, greenish-gray silicified mudstone or chert, and an upper gray shaly horizon. The lowermost units weather orange and yellow because of alteration of pyrite to jarosite (Siok, 1985). The greenish-gray to maroon siltstone and mudstone locally contain barite lenses and nodules.

The lithostratigraphic sequence of the Siksikpuk Formation is consistent throughout the Killik River quadrangle to the west and throughout the western part of the Chandler Lake quadrangle (C. G. Mull, written commun., 1987). However, in the eastern part of the Chandler Lake quadrangle, the unit consists mostly of shale and lacks a consistent chert

Overlying the Siksikpuk Formation is the Lower Triassic to Middle

Jurassic Otuk Formation, which consists of dark-gray and greenish-gray marine shale, dark-gray to black chert, and impure limestone interbedded with dark-gray and black shale (Mull and others, 1982). The chert beds typically weather brown or green. As with the Siksikpuk Formation, the Otuk Formation becomes less cherty in the eastern part of the quadrangle; the unit here is more characteristic of the Triassic Shublik Formation, which consists of primarily shale and impure limestone (Patton and Tailleur, 1964). The Otuk is distinguished from the underlying Siksikpuk Formation by the color and weathering characteristics of the chert and shale (Mull and others, 1982). The Hunt Fork Shale, Noatak Sandstone, Kanayut Conglomerate, Kayak Shale, Lisburne Group, and Siksikpuk and Otuk Formations, which form the mountains and the mountain front, comprise the Endicott Mountains allochthon, the structurally lowest allochthon in the central Brooks Range

North of the Endicott Mountains front is the southern foothills belt, which consists of primarily Mississippian to Lower Cretaceous rocks referred to by Kelley (1990) as the Arctic Foothills assemblage. The assemblage consists of Lower Cretaceous coquinoid limestone, undivided Upper Jurassic and Cretaceous strata, Jurassic mafic igneous rocks, Permian and Triassic chert, rocks of the Nuka Formation (Mississippian and Pennsylvanian?), marble, and melange.

Most of the Arctic Foothills assemblage probably is structurally repeated, complexly deformed, and tectonically disrupted (Kelley, 1990). The complexly deformed rocks are overlain by gently folded shale, graywacke, and conglomerate of the Lower Cretaceous Fortress Mountain Formation (restricted). The west-central part of the quadrangle is underlain by a thick sequence of nonresistant and tightly folded marine shale, mudstone, siltstone, and thin-bedded sandstone of the Lower Cretaceous Torok Formation (Detterman and others, 1963). The northern foothills area contains gently deformed sedimentary

rocks of the Nanushuk Group (Detterman and others, 1963; Huffman, 1989), which consists of the Lower Cretaceous Tuktu and Grandstand Formations, the Lower and Upper Cretaceous Chandler Formation, and the Upper Cretaceous Ninuluk Formation. These sedimentary rocks represent a deltaic complex composed of interbedded conglomerate, sandstone, and shale, which were derived from the Brooks Range and prograded northward and eastward into the Colville trough (Mull, 1982). This clastic wedge is folded into a series of long, linear, east-west-trending anticlines and synclines.

Overlying the Nanushuk Group in the northern Chandler Lake quadrangle are relatively small exposures of Upper Cretaceous sedimentary rocks preserved in the axes of regional synclines. These rocks consist of marine shale, siltstone, sandstone, bentonite, and tuff of the Upper Cretaceous Seabee and Schrader Bluff Formations separated by the thin nonmarine sandstone and conglomerate of the Prince Creek Formation (Detterman and others, 1963).

The geologic map shows the localities of concentrates collected in the southern part of the Chandler Lake quadrangle. Concentrates are not available from the southwestern part of the quadrangle; however, minus-30-mesh stream-sediment data are available for those areas lacking heavy-mineral-concentrate data (Barton and others, 1982). Concentrate samples collected in the northern part of the quadrangle are not discussed in this report, but are included in the discussion of sediment samples collected from the northern part of the quadrangle (Kelley and Sutley, 1993). Sample sites were selected on first- and second-order drainages

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 8-10 m 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. The sediment passing through the screen was panned using a standard gold pan to remove most of the quartz, feldspar, organic material, and clay. In the laboratory, the panned concentrate was air-dried and strongly magnetic minerals were removed with a hand magnet and discarded. Any material of low specific gravity (such as quartz and feldspar) was then removed by heavy-liquid separation using bromoform (specific gravity = 2.8). The resulting heavy-mineral fraction was then separated into nonmagnetic and magnetic fractions. The resulting nonmagnetic fraction was split into two fractions; one split was used for mineralogical analysis and the other for geochemical analysis. Details of the sample preparation procedure are described in Sutley and others (1984). The mineralogy of each concentrate sample was determined using a binocular microscope, identifying the minerals by their physical and optical properties. Occasionally, x-ray diffraction techniques were used on single grains to identify those minerals that were difficult to determine optically or to verify the analyses made by the visual examination. The split that was not used for mineralogical analysis 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 per order of magnitude (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 96-percent confidence level (Motooka and Grimes, 1976). A complete listing of the heavy-mineral-concentrate geochemical data collected from the Chandler Lake quadrangle is given in

The geochemical and mineralogical data for nonmagnetic heavy-mineral-concentrate samples were divided into two groups because the samples represent different lithologic and geologic settings. Area 1 in the western part of the quadrangle overlies primarily Mississippian to Lower Cretaceous rocks of the Arctic Foothills assemblage (Kelley, 1990), Triassic and Jurassic shale and chert, and shale, graywacke, and conglomerate of the Lower Cretaceous Fortress Mountain Formation (restricted). Area 2 in the southeastern part of the quadrangle contains Devonian to Triassic clastic rocks and Mississippian carbonate rocks. The two groups of data are treated as independent data bases in this report. We have included univariate statistics of both geochemical data sets

STATISTICAL SUMMARY

Sutley and others (1984).

in table 1. Elements that were not detected in any of the samples include Au, Sb, Th, and W; these are not included in table 1. Qualified values are those that are not detected (N), below the lower limit of determination (L), and those above the upper limit of determination (G). The detection ratio (DR) is the number of samples with unqualified values (determinant values) divided by the total number of samples analyzed. For instance, a detection ratio of 1.0 indicates that all samples yielded unqualified values for a particular element. Conversely, a detection ratio of 0.10 indicates that only 10 percent of the samples yielded unqualified values of a given element. Prior to calculation of the geometric mean and deviation, values qualified with "N" were set equal to one quarter the lower limit of determination; those qualified with "L" were set equal to one half the lower limit of determination; those qualified with "G" were set equal to twice the upper limit of determination. Only elements with a detection ratio of 0.3 or higher were used in the calculations. Eight elements were plotted on the geochemical maps: Ag, As, Co, Cr, Cu, Pb, Ni, and Zn. Concentrations of Ba exceed 10,000 ppm in 99 percent of the samples and were not plotted. However, those Ba concentrations greater than 2,000 ppm in corresponding stream sediments (Kelley and others, 1993) were plotted to show the relation to the distribution of high values of Ag, Cu, Pb, and Zn in the concentrates. Using the spectrographic intervals as class widths, histograms were constructed for each element to show the general distribution and range of the data. Based on the distribution of the data, we chose two threshold levels within the uppermost classes as representing anomalously high concentrations. Concentrations above these two levels were then plotted for each element. Less than 10 percent of the samples contained unqualified values of arsenic and, therefore,

any unqualified value was considered anomalous.

GEOCHEMICAL AND MINERALOGICAL DATA FROM AREA 1 Area 1 has poor outcrop exposure and consists of low rolling tundra-covered hills. Most streams that drain the area are slow moving, and contain either large cobbles and boulders with sparse silt-sized material or abundant silt and clay with sparse coarse material. Figure 2 shows the locations of nonmagnetic heavy-mineral concentrates collected from area 1 that contain anomalous concentrations of Ag, Cu, Pb, and Zn. Figure 3 shows the locations of samples that contain anomalous concentrations of As, Co, Cr, and Ni. The distribution of sphalerite and barite, and that of pyrite, arsenopyrite, and chalcopyrite are shown on figures 4 and 5, respectively. Because nearly every sample contains at least trace amounts of both barite and pyrite, only those concentrates containing more than 50 percent barite and more than 20 percent pyrite are plotted.

The northwestern and north-central parts of area 1 contain rocks of the Fortress Mountain Formation, which include shaly siltstone, graywacke, sandstone, and conglomerate. Locally, the unit contains minor mafic igneous clasts (Detterman and others, 1963). Small mafic volcanic bodies are located south of the Fortress Mountain Formation along the Ayiyak and Kiruktagiak Rivers. Local outcrops of Upper Jurassic and Lower Cretaceous strata, which consist of sandstone, shale, conglomerate, volcaniclastic rocks, and Permian and Triassic ribbon chert, are adjacent to the mafic igneous bodies (Kelley,

Anomalous concentrations of Ag, As, Co, Cu, Pb, Ni, and Zn occur n concentrates from the northwestern part of area 1 (figs. 2 and 3). The presence of sphalerite, barite (fig. 4), pyrite, chalcopyrite, and arsenopyrite (fig. 5) in some of the concentrates suggests that sulfides are probably disseminated within the sedimentary and igneous rocks, which comprise most of the area.

The southeastern part of area 1 contains Permian and Triassic ribbon chert, limestone and dolomite of the Lisburne Group, and minor shale and chert of the Triassic Shublik and the Triassic to Middle Jurassic Otuk Formations. Some of the concentrate samples were collected in basins draining shale, mudstone, and siltstone of the Permian Siksikpuk Formation. A few of the samples contain relatively high concentrations of Ag, Cr, Cu, and Ni (figs. 2 and 3). Because there are no sulfides in these concentrates, the values probably reflect high background concentrations of these elements and (or) the presence of mafic igneous rock fragments in the concentrates. The average Ag and Cu concentrations in silicified mudstone and shale of the Siksikpuk Formation are 1.0 ppm and 50-100 ppm, respectively. The concentrates contain 70 ppm or less Cu and 3-5 ppm Ag. The elevated Ag and Cu values in these concentrates may be due to the presence of shale fragments. The source for the high Cr and Ni concentrations is probably mafic minerals in the samples, most of which were removed during magnetic separation, but could be present in the nonmagnetic fraction in trace amounts. Magnesiochromite, a magnesium-rich endmember of the chromite solidsolution series, was not observed in these particular samples, but was identified in a few concentrates collected north of the area (Kelley and Sutley,

All of the concentrate samples collected from the southeastern part of area 1 contain more than 10,000 ppm Ba and the corresponding minus-80mesh stream-sediment samples contain more than 2,000 ppm Ba (fig. 2). Mineralogically, the samples are dominated by barite (fig. 4). The average Ba concentration in shale of the Siksikpuk Formation is 1,500 ppm. The source for the abundant barite and high Ba concentrations in the samples collected from this area is most likely barite lenses and nodules that commonly occur in the Siksikpuk Formation (Siok, 1985).

GEOCHEMICAL AND MINERALOGICAL DATA FROM AREA 2 Nonmagnetic heavy-mineral concentrates collected from area 2 containing high concentrations of Ag, As, Co, Cr, Cu, Pb, Ni, and Zn are distributed in a broad area extending from Kenunga Creek (T. 16 S., R. 5 E.)

northeastward to Thibodeaux Mountain (T. 13 S., R. 9 E.), but are generally concentrated in three separate areas: (1) the Thibodeaux Mountain area, (2) the area of Grizzly Creek that includes some tributaries to Kenunga Creek to the southwest, and (3) the Oolah Mountain area (figs. 6 and 7). Figures 8 and 9 show the distribution of sulfides and barite in concentrates collected rom area 2. It is apparent from the geochemical and mineralogical data that the anomalous concentrations of As, Cu, Pb, and Zn are directly related to the host sulfide minerals arsenopyrite, chalcopyrite, galena, and sphalerite, respectively. The Co, Cr, and Ni are probably contained in pyrite. Small amounts of Ag may also be contained in pyrite, although a moderate correlation between Ag and Pb in the geochemical data indicates that most of the Ag is probably contained in galena. Barite is present in samples collected throughout area 2, but is particularly abundant in samples collected from the rangefront north of Thibodeaux Mountain (fig. 8) and is derived from barite nodules contained in the Permian Siksikpuk Formation. In general, sphalerite is more common and more abundant than

galena in samples collected from area 2; for instance, samples collected from the Grizzly Creek drainage (T. 16 S., R. 6 E.) contain 2 to 10 percent sphalerite with only minor galena. Nearly all of the sphalerite identified in the concentrates is pale yellow. The color of sphalerite generally deepens as iron content increases and the amount of iron that can be accommodated in the sphalerite structure increases with increasing temperature (Deer and others, 1980, p. 458). On the basis of this information, it follows that the pale-yellow color of the sphalerite in the concentrates may indicate a low iron content and a low temperature of formation for the sphalerite.

> Factor Analysis of Data From Area 2 As an aid to the interpretation of the regional geochemical data from area 2, we used R-mode factor analysis with varimax rotation on log-transformed heavy-mineral-concentrate 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, based on their linear correlation coefficients (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. More than half of the samples contain qualified values for Ag, Ba, and Zn. Because there are so many qualified values, the linear correlation of these elements is based only on samples with unqualified data. We included these elements in the factor analysis because strong positive correlations between Pb and Zn, Ag and Pb, and Ba and Sr exist in the unqualified data (for example, samples with high Ag concentrations also contain high

concentrations of Pb). We assume that this correlation is consistent for all of the data including both qualified and unqualified values. We selected a five-factor model (table 2) based on factor-variance diagrams. This five-factor model, explaining 75 percent of the variance within the original data set, is the most meaningful geological 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. The distribution of samples with high scores for the five factors is Paper 303-E, 323 p. shown on figures 10 and 11. The scores for each factor were divided into

three groups on the basis of percentiles; the 99th, 95th, and 90th percentiles were chosen to represent anomalously high scores for each factor. Factors 1, 3, and 4 (table 2) account for about 51 percent of the total data variability and represent lithogeochemical associations (fig. 10). Elements that load heavily onto factor 1 include B, Cr, La, Mn, Ti, Sc, V, Y, and Zr. Most heavy-mineral-concentrate samples with high scores for this factor contain varying amounts of rutile, zircon, apatite, and sphene. These samples were collected from drainages underlain primarily by the Upper Survey Circular 591, 6 p. Devonian and Lower Mississippian(?) Kanayut Conglomerate (Nilsen and Moore, 1984), and the Upper Devonian Hunt Fork Shale. The Kanavut Conglomerate is composed of conglomerate, sandstone, siltstone, and minor shale, whereas the Hunt Fork Shale consists of shale, shaly siltstone, mudstone, and sandstone (Brosgé and others, 1979). Basins characterized by high factor 3 scores (Ca, Mg, and Y) are underlain entirely by Mississippian shale and carbonate rocks. In most areas,

Factor 4 defines concentrates containing abundant barite. The samples with high scores for this factor were collected from localities scattered throughout the eastern part of area 2. Most samples with high scores for factor 4 are from basins underlain by shale, chert, and carbonate rocks and probably reflect barite lenses and concretions contained in the Siksikpuk Formation. A few are from basins underlain by the Hunt Fork Shale or the

these rocks consist of limestone and dolomite of the Lisburne Group, with

minor amounts of the Lower Mississippian Kayak Shale (Brosgé and others,

Kanayut Conglomerate. Factors 2 and 5 represent mineralization suites (fig. 11). The Co-Cu-Fe-Mn-Ni association that characterizes factor 2 probably indicates the presence of abundant pyrite and chalcopyrite in the heavy-mineral concentrates. The Ag-Co-Cu-Pb-Zn association (factor 5) indicates the presence of galena, chalcopyrite, and sphalerite. The distribution of anomalous factor 2 scores (fig. 11) is similar to the spatial distribution of samples containing anomalous Co, Cr, and Ni (fig. 7) and the distribution of abundant pyrite and chalcopyrite (fig. 9). Likewise, samples with anomalous factor 5 scores are spatially coincident with those containing anomalous concentrations of Ag, Cu, Pb, and Zn (fig. 6) and corresponding sphalerite and galena (fig. 8). The three areas defined by high concentrations of the base metals and abundant sulfides in the concentrates (Thibodeaux Mountain. Grizzly Creek, and Oolah Mountain) are also delineated by high factor 2 scores. In addition, some samples collected from the Thibodeaux Mountain area yielded high factor 4 scores (Ba-Sc-Sr), which suggests that barite occurs with the sulfide minerals.

DISCUSSION AND INTERPRETATION OF DATA FROM AREA 2 Thibodeaux Mountain Area

North of Thibodeaux Mountain, an east-west-trending thrust fault

eparates the Upper Devonian Hunt Fork Shale from underlying, but elatively younger, shale and carbonate rocks (Brosgé and others, 1979). Mudstone, shale, sandstone, and conglomerate belonging to the lower part of the Kanayut Conglomerate and sandstone of the Noatak Sandstone (undivided on map) are stratigraphically higher than the Hunt Fork Shale. Samples collected from sites located along the tributaries of Kushuman Creek and the Nanushuk River to the west contain anomalous concentrations of Ag, Co, Cr, Cu, Ni, Pb, and Zn, and display high factor 2 and factor 5 scores. These concentrates contain trace amounts of sphalerite,

pyrite, chalcopyrite, and galena (figs. 8 and 9). Detailed examination of the

rocks at Thibodeaux Mountain revealed that pyrite (visible with hand lens) is

abundant as disseminated grains in fine- to medium-grained sandstone of the Kanayut Conglomerate. Followup studies in the northernmost east-westtrending tributary of the Itkillik River (T. 14 S., R. 7 E.) revealed numerous small sulfide-bearing veins in the Hunt Fork Shale (Duttweiler, 1986). The veins consist of pyrite, chalcopyrite, and minor galena in a gangue of quartz, calcite, siderite, and locally abundant limonite after siderite. Although sphalerite is present in concentrates collected from this area, it was not observed in the veins. Table 3 lists concentrations of selected elements in rock samples

MISCELLANEOUS FIELD STUDIES

MAP MF-2144-B SHEET 1 OF 2

collected from area 2. Rocks in the Thibodeaux Mountain area contain less than 1.0 ppm Ag, 10-100 ppm Cu, 20 to 150 ppm Pb, and 15-200 ppm Zn. The highest Cr, Fe, Pb, Ni, and Zn concentrations are in fine- to

medium-grained sandstone at Thibodeaux Mountain (samples AKD400-AKD402; table 3).

Grizzly Creek Area At the headwaters of Grizzly Creek and southwestward to tributaries Ernie and Kenunga Creeks (T. 16 S., R. 6 E. to T. 16 S., R. 5 E.), concentrate samples have high scores for the pyrite and base-metal sulfide factors (fig. 11). Sulfides, particularly sphalerite and pyrite, are widely distributed in this area (figs. 8 and 9). Nearly every sample contains 2 to 10 percent sphalerite and more than 20 percent pyrite; one sample contains minor galena. The geochemical data support the mineralogical data in that Zn concentrations of more than 10,000 ppm are common in concentrates collected from this area (fig. 6). In some samples, high Ag, Co, Ni, and Pb concentrations accompany those of Zn. One sample (sample CL730C; Sutley and others, 1984) collected from a tributary of Kenunga Creek (which drains Blackface Mountain) contains 10 ppm Ag, 1,500 ppm As, 1,500 ppm Cu, 20,000 ppm Pb, and 10,000 ppm Zn, as well as high concentrations of Co, Cr, and Fe (figs. 6 and 7). This sample contains 10 percent sphalerite, 1 percent galena, more than 20 percent pyrite, and traces of arsenopyrite and chalcopyrite (figs. 8 and 9).

At Grizzly Creek, the Lower Mississippian Kayak Shale and carbonate rocks of Mississippian age overlie the upper part of the Kanayut Conglomerate. Farther to the southwest in the area of Kenunga Creek, conglomerate, sandstone, and minor shale and siltstone of the Kanayut Conglomerate overlie the Hunt Fork Shale. In both localities, sulfides are disseminated within conglomerate and sandstone of the Kanayut Conglomerate. Throughout the Chandler Lake quadrangle, most of the strata in the upper part of the Kanayut Conglomerate are iron-stained to varying degrees. This is particularly common at Grizzly and Kenunga Creeks; oxidation of the sulfides resulted in discontinuous red-weathering layers that are widespread in the area. In addition to the disseminated sulfides, polymetallic veins occur in siltstone and shaly units, and are similar to those described at the Thibodeaux Mountain area, except that sphalerite occurs with pyrite and galena in a gangue of quartz, calcite, and siderite (Duttweiler, 1986). Several rock samples (CL783, AKD450-AKD453; table 3) containing disseminated sulfides were crushed, sieved, and panned in order to determine which sulfides were present; however, pyrite and minor arsenopyrite were the only sulfides identified. Bulk samples of these rocks contain 10-20 percent Fe; one sample of sandstone with lower Fe content contains 200 ppm Zn (table 3), indicating that trace amounts of sphalerite may be present in addition to pyrite and arsenopyrite. The vein samples contain as much as 200 ppm Zn, but concentrations of the other base metals are low.

Concentrates collected in the southeastern part of the quadrangle near Oolah Mountain (T. 15 S., R. 9 E.) contain high concentrations of Ag,

As, Pb, and Zn (fig. 6). This geochemical association is also reflected in high scores for the base-metal-sulfide factor (fig. 11). Samples collected from sites completely surrounding Oolah Mountain contain sphalerite, galena, and barite (fig. 8). On the northeast side of Oolah Mountain, concentrates contain pyrite, arsenopyrite, and chalcopyrite (fig. 9). The low concentrations of Co, Cr, and Ni explain the low scores for the pyrite factor in all samples from this The Oolah Mountain area consists primarily of rocks of the Upper

Devonian Hunt Fork Shale and Upper Devonian and Lower Mississippian(Kanayut Conglomerate. Further study of the geochemical anomalies revealed numerous quartz-calcite veins hosted by the shale member of the Hunt Fork Shale and sandy subunits of the Kanayut Conglomerate. However, very few sulfides were observed in the veins, with the exception of minor pyrite (mostly Unmineralized shale and siltstone collected from the northeast side

of Oolah Mountain contain 500 ppm Ba, 50-70 ppm Cu, 20 ppm Pb, and 120-180 ppm Zn (samples CL773R2 and CL773R3; table 3). Most of the rocks containing visible pyrite contain 500 ppm Ba, 70 ppm Cu, 30 ppm Pb, and less than 80 ppm Zn (table 3).

suggests that sulfides may be disseminated in sedimentary and igneous rocks

CONCLUSIONS The geochemistry and mineralogy of concentrates collected from area

in the northeastern and north-central parts of area 1. In addition, barite is common in the Siksikpuk Formation and is reflected by high concentrations of Ba in heavy-mineral concentrates and minus-80-mesh stream sediments collected in basins draining rocks of the Siksikpuk Formation. Moderately high Ag and Cu concentrations most likely result from high background levels of these metals in the shale. The geochemistry of heavy-mineral concentrates collected from area 2 suggests that there are three areas that are favorable for base-metal sulfide occurrences: the Thibodeaux Mountain area, the Grizzly Creek area, and the

Oolah Mountain area. The disseminated sulfides and the polymetallic veins hosted by the Hunt Fork Shale and Kanayut Conglomerate found in these three areas were probably formed by dewatering or low-grade metamorphism of the shale and sandstone in the Hunt Fork Shale. The thick, porous strata of the overlying Kanayut Conglomerate are permeable enough to make host rocks for upward-migrating mineralizing fluids derived from compaction of the REFERENCES CITED

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MAPS SHOWING GEOCHEMISTRY AND MINERALOGY OF NONMAGNETIC HEAVY-MINERAL-CONCENTRATE SAMPLES FROM THE SOUTHERN PART OF THE CHANDLER LAKE QUADRANGLE, ALASKA

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