DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-2021-D
FOLIO OF THE MOUNT KATMAI AREA

MAP A

Base from U. S. Geologic Survey Afognak and Naknek, 1952,
Mount Katmai, 1951, with minor revisions 1972.

EXPLANATION

Chalcopyrite
Pyrite — Wulfenite
Sphene — 98% 95% 90%
Rutile — Galena
Sphalerite

Mineralogical sample site--Vectors, centered around the sample locality, showing the distribution of chalcopyrite, wulfenite, galena, sphalerite, pyrite, sphene, and rutile. Each filled vector of the star diagram represents the relative abundance of a specific mineral recovered from a single 14-in. gold pan of sediment. The length of the vector indicates the relative abundance (estimated visually in percent) of the mineral present in the sample (table 1). The heavy dashed contour encloses all the drainage basins that contained more then 25 percent total sulfide in the nonmagnetic heavy-mineral-concentrate samples (see figure 1).

Geologic Base from Riehle and others (1987)

MAP B

Base from U. S. Geologic Survey Afognak and Naknek, 1952,
Mount Katmai, 1951, with minor revisions 1972.

EXPLANATION

Arsenopyrite
Cassiterite — Scheelite
Stibnite — 90% 95% 98% — Gold
Barite — Cinnabar

Mineralogical sample site--Vectors, centered around the sample locality, showing the distribution of arsenopyrite, scheelite, gold, cinnabar, barite, stibnite, and cassiterite. Each filled vector of the star diagram represents the relative abundance of a specific mineral recovered from a single 14-in. gold pan of sediment. The length of the vector indicates the relative abundance (estimated visually in percent) of the mineral present in the sample (table 1).

Geologic Base from Riehle and others (1987)

SCALE 1:250 000

5 0 5 10 15 MILES
5 0 5 10 15 KILOMETERS

CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

CORRELATION OF MAP UNITS

Surficial Deposits and Sedimentary Rocks: Qs, Qls; unconformity; Tc; unconformity; Kk; unconformity; Kp; local unconformity; Kh; unconformity; Ks; unconformity; Jn; unconformity; Jt; Tsk; Jpk
Volcanic Rocks: Qac, Qap, Qad, QTac, QTap; Tav; Tnb, Tma; Tgd, Tqd, Tgb; Jgd, Jqd, Jgr, Jgb
Intrusive Rocks: Ti; d; Tiu
Metamorphic Rocks: Ts; Th; Tsc; JPk

Holocene and Pleistocene — QUATERNARY
QUATERNARY AND/OR TERTIARY
Upper Tertiary
TERTIARY
Upper Cretaceous
Lower Cretaceous
CRETACEOUS
Upper Jurassic
Lower Jurassic
JURASSIC
Upper Triassic
Lower Jurassic to Upper Permian
TRIASSIC
JURASSIC, TRIASSIC, AND PERMIAN

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS AND SEDIMENTARY ROCKS

Qs **Surficial deposits (Holocene and Pleistocene)**--Unconsolidated to poorly consolidated alluvial, colluvial, glacial, marine, lacustrine, and eolian deposits. Locally includes extensive redeposited pumice and ash initially deposited during the 1912 Katmai eruption

Qls **Landslide deposits (Holocene and Pleistocene)**--Nonsorted, nonstratified coarse angular rubble forming lobate masses

Ts **Sedimentary rocks (Tertiary)**--Poorly to moderately well indurated, fluvial sandstone, siltstone, and conglomerate; larger clasts consist of both plutonic and volcanic rocks of local derivation

Th **Hemlock Conglomerate (Oligocene)**--Poorly indurated fluvial conglomerate, pale brown tuffaceous sandstone, siltstone, shale, coal, and tuff. Age is late Oligocene

Tc **Copper Lake Formation (Tertiary)**--Massive, well indurated, polymictic conglomerate, sandstone, and siltstone. Age is early Tertiary

Kk **Kaguyak Formation (Late Cretaceous)**--Upper part consists of interbedded siltstone and graded greywacke sandstone that represent the upper and middle reglmes of a submarine fan. Lower part consists of thinly bedded siltstone and some thin limestone beds and includes abundant ammonites, pelecypods, and limestone concretions

Kp **Pedmar Formation (Early Cretaceous)**--Thick-bedded grey sandstone and minor amounts of siltstone and shale that contain ammonites of Albian age

Kh **Herendeen Formation (Early Cretaceous)**--Calcareous sandstone and siltstone, thinly bedded, light- to dark-olive grey

Ks **Staniukovich Formation (Early Cretaceous)**--Siltstone, shale, and thinly bedded, fine-grained, feldspathic and laumontitic brown sandstone

Jn **Naknek Formation (Late Jurassic)**--Main sedimentary rock-unit of the map area, consisting of sandstone, conglomerate, siltstone, and dark shale. Divided into five members (not mapped here), from oldest to youngest: massive conglomerate and thinly bedded sandstone member; thick-bedded to massive sandstone member; thinly bedded, dark grey siltstone member with limestone concretions; thinly bedded sandstone and siltstone member; massive conglomerate member. Clasts in both the oldest and youngest conglomerate members are dominantly metamorphic, volcanic, and sedimentary rocks with subordinate plutonic rocks

Jt **Talkeetna Formation (Early Jurassic)**--Lava flows, breccias, and lahars locally interbedded with volcaniclastic sandstone, conglomerate, and shale. Includes sills of uncertain ages. Metamorphosed to non-schistose epidote-albite-calcite assemblages suggestive of lower greenschist facies

Jpk **Kamishak Formation (Late Triassic)**--Slightly to moderately recrystallized, non-fossiliferous limestone

VOLCANIC DEPOSITS AND ROCKS

Younger deposits and rocks of Aleutian volcanic arc

Qap **Pyroclastic-flow deposits (Holocene)**--Poorly sorted, variably indurated deposits of ash, vitrophyric blocks, and (or) pumiceous lapilli. Comprises the 1912 ash flow of Katmai (Novarupta) and the Holocene block-and-ash flows of Kaguyak caldera

Qad **Domes (Holocene)**--Domes of dacitic or rhyolitic composition

Qac **Younger central-vent deposits and rocks (Holocene and Pleistocene)**--Lava flows, tuffs, and breccias dominantly of andesitic composition but locally including lava flows of low-silica dacitic composition, airfall deposits of andesitic to rhyolitic composition on Baked Mountain and Broken Mountain, and scoria cones of basaltic composition

QTap **Pyroclastic-flow deposits (Pleistocene and late Tertiary)**--Poorly sorted, variably indurated deposits of ash, vitrophyric blocks, and/or pumiceous lapilli. Primary compositions are uncertain owing to alteration but probably range from andesitic to dacitic

QTac **Older central-vent deposits and rocks (Pleistocene and late Tertiary)**--Lava flows, breccias, and domes of andesitic and dacitic composition. Locally moderate to extensive alteration associated with fossil fumaroles (e.g., bleaching to light red or yellow shades)

Tav **Older volcanic rocks of Aleutian volcanic arc (late Tertiary)**--Breccias, lava flows, sills, and local pyroclastic and epiclastic tuffs of late Tertiary volcanic field located southeast of the Aleutian Range crest and extending from the Katmai River to Kukak Bay. Dominantly of andesitic and dacitic composition. Propylitic alteration is extensive and argillic or advanced argillic alteration is locally intensive, such as near contacts with hypabyssal intrusive rocks of unit Ti

Volcanic rocks of Meshik volcanic arc (early Tertiary)--Divided into:

Tmb **Basaltic lava**--Plugs, dikes, and flows of basaltic composition that intrude or overlie rocks of unit Tma

Tma **Andesitic and dacitic lava flows and breccia**--Unit also includes local domes or tuffs of rhyolitic(?) composition, now altered to quartz and sericite or kaolinite

METAMORPHIC ROCKS

JPk **Kaikhonak Complex (Jurassic, Triassic, and Permian?)**--Locally foliated or banded quartzite, schist, amphibolite, and garnet-bearing gneiss indicative of amphibolite-facies metamorphism. Protoliths presumably consisted of Talkeetna Formation (Jt), Kamishak Formation ([Jk), Cottonwood Bay Greenstone ([Jc), and unnamed Permian(?) sandstone and argillite

[Jc **Cottonwood Bay Greenstone (Late Triassic)**--Basalt flows now metamorphosed to epidote-albite-actinolite assemblages suggestive of greenschist facies; also locally includes chert and fine- to medium-grained diabase

INTRUSIVE ROCKS

d **Dikes (Tertiary)**--Dikes from 1 m to 20 m wide that occur southeast of the Bruin Bay fault, that is, in rocks no older than the Naknek Formation (Jn). Many are in rocks as young as the Hemlock Conglomerate (Th), however, suggesting that most are middle to late Tertiary in age

Ti **Hypabyssal intrusive rocks of Aleutian volcanic arc (late Tertiary)**--Sill-like or cross-cutting subvolcanic intrusive bodies generally less than 10 sq km in outcrop area, as well as larger plutonic bodies such as those beneath Fourpeaked volcano or along the Aleutian Range crest east of Serpent Tongue Glacier. Fine-grained, porphyritic to equigranular rocks that consist dominantly of granodiorite or tonalite and minor quartz diorite

Tiu **Hypabyssal intrusive rocks, undivided (Tertiary)**--Intrusive bodies ranging from small plugs and sills to plutons exposed over as much as 30 sq km. Rocks are fine- to medium-grained, commonly porphyritic, and consist chiefly of quartz diorite or tonalite

Tgd **Granodiorite (Tertiary)**--Medium-grained equigranular to marginally porphyritic rocks that are low in modal quartz; unit includes samples that are classified as quartz monzodiorites

Tqd **Quartz diorite (Tertiary)**--Medium-grained equigranular rocks in which abundance of modal quartz ranges widely, rocks of the unit include tonalite and monzonite

Tgb **Gabbro and diorite (Tertiary)**--Medium-grained rocks having gabbroic or diabasic textures

Jgr **Granite (Jurassic)**--Medium-grained equigranular or fine-grained porphyritic rocks

Jgd **Granodiorite (Jurassic)**--Medium-grained equigranular or fine-grained porphyritic rocks. Also includes isolated outcrops of tonalite and quartz diorite

Jqd **Quartz diorite and tonalite (Jurassic)**--Medium-grained equigranular rocks

Jgb **Diorite and gabbro (Jurassic)**--Dark, diabasic- and gabbroic-textured rocks

GEOLOGIC MAP SYMBOLS

Contact--Dashed where inferred or approximately located

Fault--Dashed where inferred or approximately located, dotted where concealed; queried where uncertain. D-up-thrown side, D-down-thrown side

Thrust or reverse fault--Sawteeth on upper plate; bar with number indicates dip of fault plane

Anticlinal axis--Showing direction of plunge; dashed where approximately located; dotted where concealed; queried where existence uncertain

Area of hornfels

Synclinal axis--Showing direction of plunge; dashed where approximately located; dotted where concealed; queried where existence uncertain

Measured strike and dip of beds

Approximate strike and dip of beds

Strike and dip of foliation

Horizontal bedding

Dike

Quaternary volcanic vent

Area of alteration

STUDIES RELATED TO AMRAP

The U.S. Geological Survey is required, by the Alaskan National Interests Lands Conservation Act (ANILCA, Public Law 96-487, 1980), to survey certain Federal lands to determine their mineral values, if any. 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 the results of a mineralogical study of the nonmagnetic heavy-mineral-concentrate fraction of stream sediments collected during a reconnaissance survey of the Mount Katmai quadrangle, and parts of the Afognak and Naknek quadrangles, Alaska.

INTRODUCTION

During the summers of 1983-85, we conducted a reconnaissance geochemical and mineralogical survey of the Mount Katmai quadrangle and parts of the Afognak, Naknek, and Iliamna quadrangles, Alaska. The study area comprises approximately 10,000 mi² (26,000 km²) in the northern part of the Alaska Peninsula. The villages of Naknek and King Salmon lie west of the study area. The study area encompasses all of the Katmai National Park and Preserve, as well as a part of the McNeil State Game Preserve.

The topographic relief in the study area is 7,090 ft (2,170 m), with a maximum altitude at the summit of Snowy Mountain. The terrain in the central and eastern parts of the Katmai study area is rugged and mountainous and contains youthful stream drainages in previously glaciated valleys. The Valley of Ten Thousand Smokes, formed by infilling of ash flows from the Mount Katmai eruption of 1912 (Fenner, 1920), has been deeply incised and was not sampled. The western part of the Katmai study area is a low tundra plain covered by a deep mantle of glacial, lacustrine, and eolian deposits. There are no outcrops of bedrock exposed. Large glacial lakes preserved in the area were formed behind terminal moraines after the retreat of the glaciers (Keller and Reiser, 1959).

Sampling was confined largely to the alpine and foothills terrains in the eastern and central parts of the Katmai study area. Two different kinds of were sampled: (1) stream sediments, and (2) nonmagnetic heavy-mineral concentrates panned from the stream sediments. The minus-80-mesh stream-sediment medium reflects changes in bedrock geology and geochemistry, and also reveals areas of extensive exposed mineralization, whereas the nonmagnetic heavy-mineral-concentrate medium will concentrate the ore-related minerals present and may be useful in delineating small areas of poorly exposed mineralization.

This report, one of a series of reports that graphically present selected geochemical and mineralogical data in map format, presents mineralogical data from binocular microscopic examination of nonmagnetic heavy-mineral-concentrate samples; MF-2021-A (Church and others, 1989) presents the geochemical results from emission spectrographic analysis of minus-80-mesh stream-sediment samples; MF-2021-B (Church and Motooka, 1989) presents the results from inductively coupled plasma analysis of leachable metals from the minus-80-mesh stream-sediment samples; and MF-2021-C (Church and Arbogast, 1989) presents geochemical results from emission spectrographic analysis of nonmagnetic heavy-mineral-concentrate samples. An interpretive report, which delineates selected areas of mineralization within the Katmai study area and interprets the significance of the geochemical and mineralogical signatures of these anomalous areas, is in preparation.

GEOLOGY

Geologic mapping of the Mount Katmai region includes early reconnaissance work by Keller and Reiser (1959) and preliminary results of the AMRAP study (Riehle and others, 1987). Stratigraphic relations and age determinations on rocks from the study area (M.A. Lanphere and F.H. Wilson, written commun., 1988). Roof pendants are a heterogeneous assemblage of schist, gneiss, quartzite, greenstone, and amphibolite (JPk), the protoliths of which include Jurassic volcanic rocks (Jt), Triassic basalt flows and limestone (Tk c and Tk k), and possibly older sedimentary and (or) volcanic rocks.

Extrusive rocks (Tmb, Tma) of middle Tertiary age (F.H. Wilson, written commun., 1987) are part of the Meshik volcanic arc, which extends from the southern Alaska Peninsula north to the Katmai region and perhaps into the Iliamna quadrangle (Wilson, 1985). Tertiary plutons of the Alaska-Aleutian Ranges batholith may, in the Iliamna quadrangle, be the deep-seated equivalents of the Meshik volcanic rocks. Centers of Miocene volcanism (Tav), located immediately seaward of the currently active Quaternary vents (Qap, Qad, and Qac), document the onset of the modern Aleutian arc. Younger rocks (QTap, QTac) that are located near and are more deeply eroded than, Quaternary volcanic rocks, may be intermediate in age between the older and younger parts of the arc. Shallow intrusions of late Tertiary (Ti) and Tertiary (Tiu) age have locally metamorphosed and (or) hydrothermally altered the older Miocene volcanic rocks east of the range crest as well as the Mesozoic sedimentary rocks west of the range crest.

The most extensive rock unit in the region is the Naknek Formation (Jn), a composite of Upper Jurassic shallow marine, littoral, and fluvial conglomerates, sandstones, and siltstones that document the unroofing and erosion of the Jurassic part of the batholith. Younger strata locally preserved in the study area are Cretaceous sandstone, siltstone, and calcareous sandstone (Ks, Kp, Kh, and Kk) and Tertiary conglomerate, sandstone, and siltstone, locally tuffaceous and (or) coal-bearing (Ts, Th, and Tc). The main structural feature of the study area is the Bruin Bay fault, a high-angle reverse fault 480 km in length (Detterman and Hartsock, 1966; Detterman and others, 1976) that, in the Katmai study area, juxtaposes the batholith and older rocks on the west against the Naknek Formation on the east. Other structural features include north- to northeast-trending folds and northwest-trending, high-angle minor faults, fractures, veins, and dikes; most or all of such features in the study area are probably late Tertiary in age.

SAMPLE COLLECTION, PREPARATION, AND ANALYSIS

We collected heavy-mineral-concentrate samples from active alluvium in the high-energy portion of the stream. Sample sites were primarily from first-order (unbranched) and second-order (below the junction of two first-order) streams, as shown on U.S. Geological Survey topographic maps (scale, 1:63,360). We collected these panned-concentrate samples from a total of 1038 stream sites. Sample density was about one sample site per 9 mi² (13 km²); areas covered by glacial material were not sampled. The area of the drainage basins sampled ranged from 2 mi² (5 km²) to about 10 mi² (26 km²). Each bulk sample was screened with a 10-mesh (2.0-mm) screen to remove the coarse material. The less than 2.0-mm fraction was panned until most of the quartz, feldspar, organic material, and clay-sized material were removed.

After air drying in the field, the samples were sent to the laboratory for mineral separation. The samples were sieved to minus-30-mesh (0.6 mm) and the remaining quartz and feldspar was separated from the heavy-mineral-concentrate fraction using bromoform (specific gravity about 2.8). The resultant heavy-mineral-concentrate sample was separated into three fractions using a large electromagnet (Bailey and others, 1986). The most-magnetic, first-fraction material, primarily magnetite, and a second fraction, largely ferromagnesian silicates and iron oxides, were not analyzed. The third fraction (the least-magnetic material, which may include the nonmagnetic ore minerals, zircon, sphene, and so forth) was examined to determine the mineralogy of the sample and then split using a Jones splitter. One split was hand-ground for spectrographic analysis; the other split was archived for future work. We reported mineralogical results from 961 of the 1038 sites (Bennett and Church, 1987). Analytical results obtained by emission spectrographic methods for the nonmagnetic heavy-mineral-concentrate samples are given in Bailey and others (1986; table 3, p. 70-126).

Mineral identifications were made by visual examination of the sample using a binocular microscope to identify ore and ore-related minerals. In most cases, the mineral grains could be identified from their physical properties, such as hardness, cleavage, and crystal form, or fluorescence (ultraviolet light at a wavelength of 200 nm); however, x-ray diffraction was used to confirm the identifications where weathering or abrasion destroyed the crystal form. Through comparison of the mineralogical identifications with the geochemical data, geochemical anomalies from the concentrates (Church and Arbogast, 1989) may be related to an identified suite of minerals representing mineralization and alteration. Anomalies may also be attributed to the presence of contamination from lead shot or copper wire, or in the case of placers, to liquid mercury used to recover gold. Visual examination can identify geochemical anomalies that result from incomplete separation of mafic silicates; several important trace elements substitute readily in the crystal lattices of the slightly magnetic rock-forming minerals. In addition, visual examination of the nonmagnetic fraction enhances the probability of finding gold or native metals. Malleable metals, such as gold, are not uniformly dispersed during the grinding process and, therefore, may not be detected by spectrographic analysis.

Duplicate samples were taken at 62 sites and replicate analyses were made of 16 of these duplicate samples. We split the duplicate material was recovered for mineralogical analysis of both splits. Estimates of the percent sulfides in the replicate samples were usually in agreement. Although an analysis of variance is, in the strictest sense, inappropriate for these data because the data are grouped in geometrically spaced classes and because much of the data are censored, an analysis of variance for the abundance of pyrite determined in the duplicate samples indicated that most of the variation within the data set (65%) is between sample localities rather than between duplicate sites.

A statistical summary of the mineralogical observations from 961 nonmagnetic heavy-mineral-concentrate samples is given in table 1. The histogram in figure 1 shows the distribution of the percent sulfide, estimated by visual examination of the sample population. The heavy dashed contour shown on map A represents the outline of the drainage basins of all samples having more than 25 percent total sulfide minerals in the heavy-mineral-concentrate sample. Areal distribution of twelve ore-related minerals that may reflect mineralization or alteration are shown on maps A and B. The mineral suites reflect the primary sulfide phase of elements indicating mineralization, and are plotted on the same vector as the corresponding elements in the geochemistry maps of the nonmagnetic heavy-mineral concentrates (Church and Arbogast, 1989). The star diagrams are not completely filled, but contain primarily those minerals that reflect mineralization or related suites; all vectors radiate from the sample localities, which are shown as small circles. When sufficient data were available (table 1), the rays were subdivided into three lengths corresponding to selected percentage ranges of the mineral in the sample. A brief interpretation of the work done in the eastern part of the Katmai study area was reported in Goldfarb and others (1988).

Within the area south and southwest of Cape Douglas, pyrite, chalcopyrite, sphalerite, barite, and wulfenite commonly occurred and galena, arsenopyrite, scheelite, and gold were less commonly identified. In the area of the Tertiary volcanic rocks (Tav) in the southern part of the Katmai study area, the minerals pyrite, wulfenite, sphalerite, and arsenopyrite commonly occurred and cinnaber, chalcopyrite, galena, and gold were less commonly identified. Within the several areas identified as having porphyry-copper suites (Church, Bailey, and others, 1989; Church and Motooka, 1989; Church and Arbogast, 1989) the minerals pyrite, chalcopyrite, sphalerite, and barite commonly occurred whereas galena, wulfenite, and arsenopyrite were less common and stibnite and gold were identified in only isolated or single occurrences. Pyrite, sphene, and barite were common heavy-mineral suites derived from drainages underlain by the Naknek Formation (Jn), but occassionally, cassiterite and scheelite were also identified in the heavy-mineral suites collected from these drainages.

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TABLE 1.--Statistical summary of the mineralogical data for nonmagnetic heavy-mineral concentrates from the Mount Katmai and parts of the Afognak and Naknek quadrangles, Alaska

[Of the 1038 heavy mineral concentrate samples, 961 had sufficient recoveries so that both the mineralogy and the chemistry could be done on the sample. Unqualified population is one in which mineral concentrations can be estimated. Abundances are expressed as a percentage of the total nonmagnetic heavy-mineral concentrate. The detection limit for a mineral in samples in which the mineral was positively identified divided by the total number of samples examined (N = 961). Leaders (--) denote no data or insufficient data; < = less than; > = greater than.]

Mineral	Data based on entire sample population: N	DR	Number of samples in which the mineral was identified	Range of values	Distribution (by percent based on visual estimate): Selected ranges Short vector	Medium vector	Long vector
Map A							
Chalcopyrite	861	.104	100	<1-5	--	<1	>1
Wulfenite	922	.041	39	<1	--	--	<1
Galena	903	.055	58	<1-15	--	<1	>1
Sphalerite	881	.083	80	<1-15	--	<1	>1
Rutile	874	.091	87	<1	--	--	<1
Sphene	795	.173	166	<1-50	<1	1-5	>5
Pyrite	207	.207	754	<1->95	5-15	20-50	>50
Map B							
Arsenopyrite	907	.056	54	<1-15	--	<1	>1
Scheelite	906	.057	55	<1-15	--	<1	>1
Gold	946	.016	15	<1	--	--	<1
Cinnabar	954	.007	7	<1	--	--	<1
Barite	735	.235	226	<1-15	<1	1-5	>5
Stibnite	958	.003	3	<1	--	--	<1
Cassiterite	955	.006	6	<1	--	--	<1

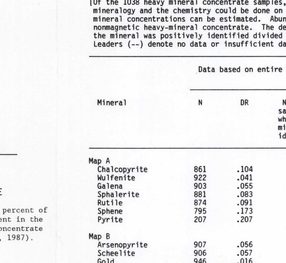

Figure 1. Histogram showing the percent of total sulfide minerals present in the nonmagnetic heavy-mineral-concentrate samples (Bennett and Church, 1987).

MINERALOGICAL MAPS SHOWING THE DISTRIBUTION OF SELECTED MINERALS IDENTIFIED IN NONMAGNETIC HEAVY-MINERAL CONCENTRATES FROM THE MOUNT KATMAI AND PARTS OF THE AFOGNAK AND NAKNEK QUADRANGLES, ALASKA

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