Geochemical Survey of the Valdez 1°×3° Quadrangle, South-Central Alaska

U.S. GEOLOGICAL SURVEY BULLETIN 2084

Cover. View to southwest of Tebay Lakes. Tebay Lakes occupy a glacially sculpted drainage divide in the Chugach Mountains within Wrangell-St. Elias National Park. The foreground ridge consists of fault-bounded slices of greenschist- and lower amphibolite-grade metasedimentary, metavolcanic, and metaplutonic rocks of the southern Wrangellia terrane margin. These rocks contain anomalous amounts of cobalt and copper in many places and host disseminated and massive sulfide occurrences including the nickel-rich deposits near Spirit Mountain, just beyond the right edge of the view. The glacier-clad crests of the Chugach in the background are carved from subduction assemblages of the Chugach terrane, which is host for numerous gold-bearing vein deposits including those of the Bremner district, just beyond the left edge of the view. Photograph by G.R. Winkler, July 18, 1978.

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By Richard J. Goldfarb, J. Carter Borden, *and* Gary R. Winkler

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Geochemical Survey of the Valdez 1°×3° Quadrangle, South-Central Alaska

By Richard J. Goldfarb, J. Carter Borden, *and* Gary R. Winkler

ABSTRACT

A reconnaissance stream-sediment geochemical survey was conducted across the Peninsular, Wrangellia, Chugach, and Prince William terranes in the Valdez 1°×3° quadrangle, south-central Alaska. The resulting 606 –80-mesh stream- and moraine-sediment samples and 453 heavy-mineral-concentrate samples were analyzed by semiquantitative emission spectrography and atomic absorption spectrophotometry. The spatial distribution of the data was examined using individual-element concentration plots and R-mode factor analysis score plots. Geochemical data also were interpreted for 457 –100-mesh stream-sediment, 500 –100-mesh lake-sediment, 520 stream-water, and 685 lake-water samples collected during the U.S. Department of Energy's National Uranium Resource Evaluation (NURE) survey of the quadrangle. Sediment samples from the NURE survey were analyzed for a variety of elements by delayed neutron counting, X-ray fluorescence, arc-source emission spectrography, and instrumental neutron activation analysis; water samples were only analyzed for uranium by delayed neutron counting methods.

Thirty-one areas delineated by the presence of geochemically anomalous samples were identified through interpretation of the geochemical data bases. Some of these areas identify new locations favorable for the occurrence of metallic mineral resources, whereas others delineate and expand the boundaries of known mining districts.

Two-thirds of the anomalous areas are within the metasedimentary-rock-dominated units of the Chugach terrane. Anomalous concentrations of gold, silver, arsenic, iron, copper, lead, and zinc in both sediment and concentrate samples reflect a high geochemical favorability for the presence of mesothermal gold-bearing quartz veins. The largest of these areas covers about 750 km^2 between Columbia Glacier and the Lowe River and includes the mines and prospects of the Port Valdez mining district. Anomalous concentrations of iron, cobalt, nickel, and copper in samples from the south-central edge of the Valdez quadrangle, between Solomon Gulch and Schwan Glacier, indicate the upstream presence of disseminated sulfides and massive sulfide pods. These volcanogenic occurrences are spatially associated with mafic volcanic rocks within the Chugach terrane. Concentrate samples containing 5,000 or more ppm Mn, and less commonly stream-sediment samples containing anomalous concentrations of manganese, characterize the area between Bench and Marshall Glaciers and the southeast corner of the study area. The anomalous concentrations of manganese most likely were produced through weathering of recognized manganese enrichments in phyllite and schist. Clusters of NURE stream-sediment samples along the Bremner River and in the Tiekel River–Stuart Creek area containing anomalous amounts of uranium probably reflect uranium-enriched silicate minerals in the Chugach metamorphic complex and felsic dike swarms, respectively.

Stream-sediment samples containg consistently anomalous concentrations of cobalt and copper, and less consistent anomalous concentrations of silver, chromium, iron, nickel, lead, and zinc, are derived from Wrangellia terrane rocks south of the Chitina River. The anomalies define geochemically favorable ground for both disseminated and massive volcanogenic, copper-sulfide-dominant mineral occurrences associated with mafic volcanic rocks and magmatic cobalt- and nickel-rich occurrences in ultramafic rocks. North of the Chitina River, samples collected near Sheep Mountain and Alice Peak contain anomalous amounts of copper, boron, vanadium, antimony, barium, zinc, and molybdenum. Some of the anomalies reflect known volcanogenic copper occurrences, but the source for other anomalies is uncertain. The cause of the broad anomaly for uranium in both lake-sediment and lake-water samples in unconsolidated sediments within the lower Cheshnina and Chetaslina river basins is also uncertain.

A large region likely to contain chromite lenses within ultramafic rocks of the Peninsular terrane is defined around Bernard and Dust Creeks by stream-sediment samples that contain anomalous concentrations of chromium, iron, nickel, magnesium, and vanadium. A similar suite of elements at anomalous levels characterizes both sediment and concentrate samples collected along the Border Ranges

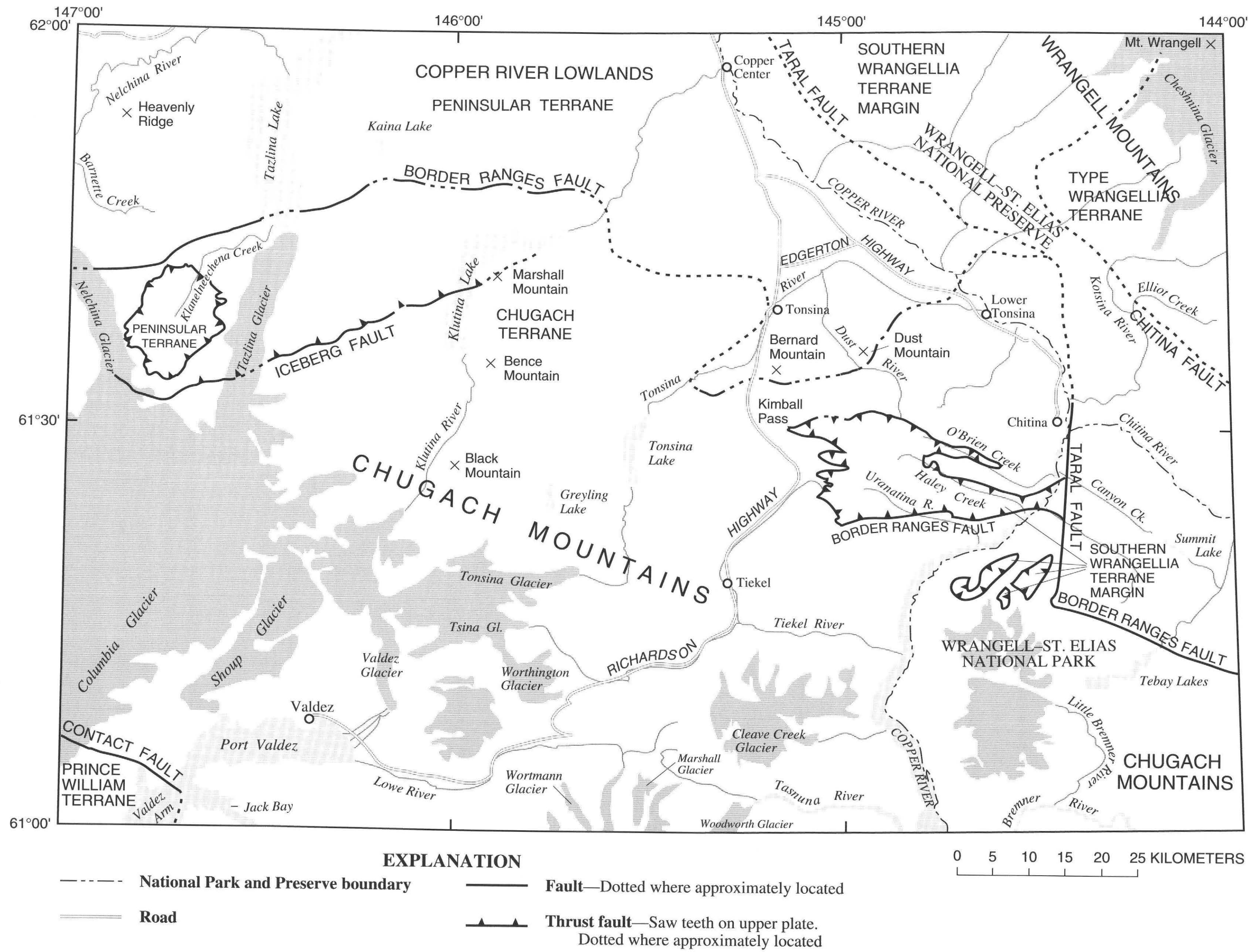


Figure 1. Major physiographic features and tectonostratigraphic terranes of th Valdez 1°×3°quadrangle, Alaska. The quadrangle is underlain by rocks of the Wrangellia, Peninsular, Chugach, and Prince William terranes. The Wrangellia terrane is subdivided into the type Wrangellia and the southern Wrangellia terrane margin.

fault system between Barnette and Klanelneechena Creeks. Samples containing anomalous amounts of gold, silver, and boron suggest precious-metal-bearing occurrences in a small area of the Peninsular terrane along the east side of Klanelneechena Creek.

INTRODUCTION

A stream-sediment geochemical reconnaissance survey was conducted in the Valdez 1°×3° quadrangle (fig. 1), south-central Alaska, in 1978–79. The survey was part of the Level III Alaska Mineral Resources Assessment Program (AMRAP) studies conducted at 1:250,000 scale. Composite stream-sediment and heavy-mineral-concentrate samples were collected during this survey; the data are reported in Miller and others (1982) and are evaluated in detail in this report.

Stream-sediment data are also examined from a number of other geochemical surveys carried out within the Valdez quadrangle. Stream-sediment and concentrate samples were collected in the early 1980's at 98 sites south of lat 61°10′ N. as a part of the Chugach National Forest Wilderness study (Goldfarb and others, 1984). Stream-sediment, lake-sediment, and water samples were collected from much of the Valdez quadrangle area by the Los Alamos National Laboratory for the U.S. Department of Energy's National Uranium Resource Evaluation (NURE) program (Sharp and Hill, 1978; D'Andrea and others, 1981; Los Alamos National Laboratory, 1983). In a detailed study of massive sulfide mineralization southeast of Port Valdez, Rose (1965) collected about 80 –80-mesh stream-sediment samples. Jasper (1967) collected 102 stream-sediment and heavy-mineral-concentrate samples for chemical analysis and microscopic examination, respectively, alongside roads in the Valdez quadrangle. Herreid (1970) carried out detailed stream-sediment, soil, and rock-chip sampling in the vicinity of the Spirit Mountain nickel-copper prospect. Stream-sediment and heavy-mineral-concentrate samples were collected around the ultramafic and mafic rocks at Bernard Mountain by Sutley and others (1990) as part of a geochemical exploration study of south-central Alaska.

Most of the Valdez quadrangle lies within the rugged and glaciated Chugach Mountains (fig. 1), in which peaks reach elevations close to 2,700 m in the southwest. In the southwest corner of the quadrangle, in the Port Valdez–Valdez Arm area, the mountains extend down to tidewater. To the north, the Chugach Mountains give way to the broad plains of the Copper River Lowlands. Glacier-covered, shield and composite volcanoes of the Wrangell Mountains occupy the northeast corner of the study area; maximum elevation of this area is 4,252 m on Mount Wrangell. The Copper River, flowing north to south across the eastern part of the quadrangle, transects the Copper River Lowlands and the Chugach Mountains.

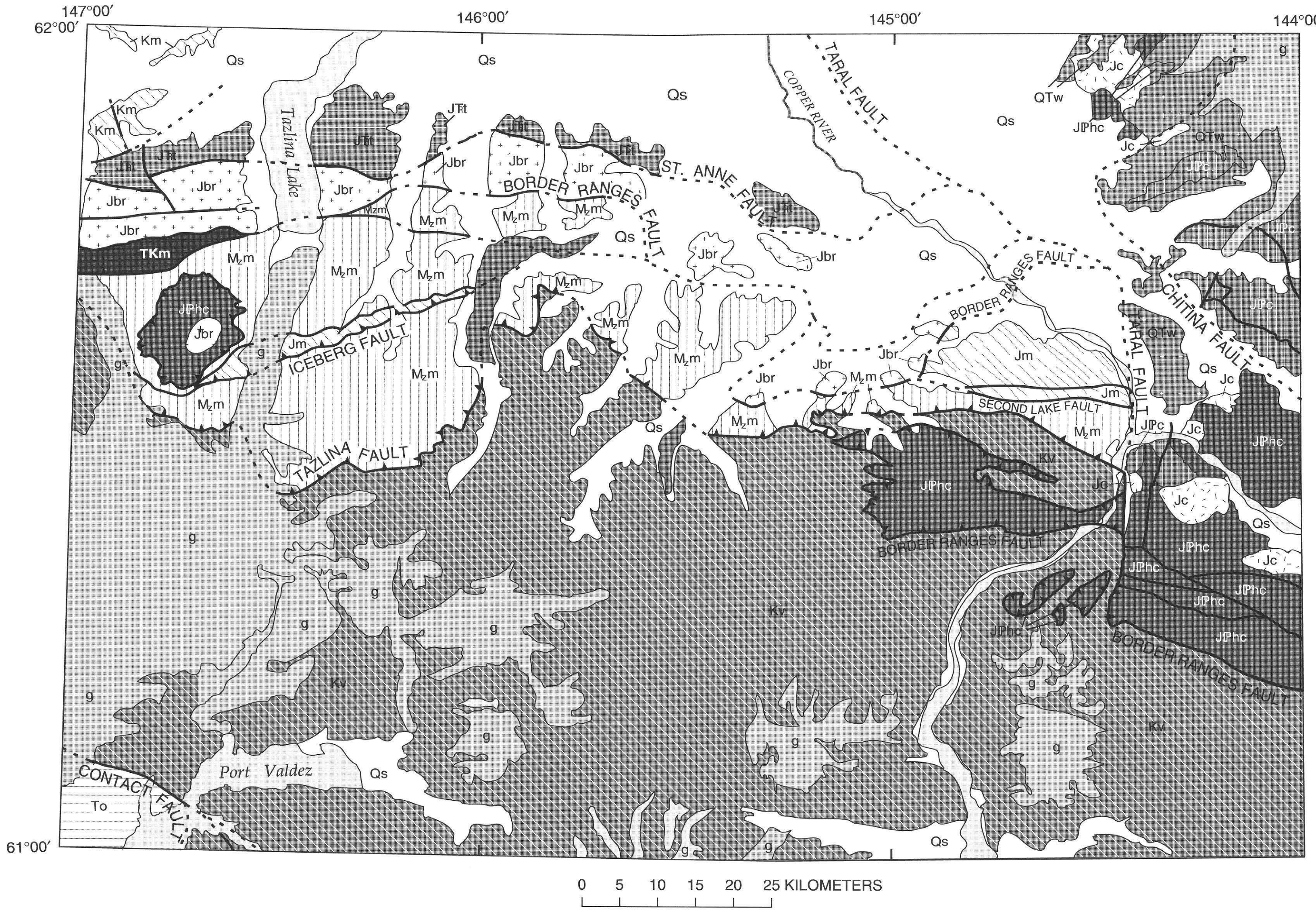
Most of the land east of the Copper River is within Wrangell–St. Elias National Park and Preserve (fig. 1). Much of the southwest part of the study area is within the Chugach National Forest. The Richardson Highway cuts through the middle of the quadrangle, from Copper Center to Valdez, providing limited access to some areas. The city of Valdez is also accessible by boat from Prince William Sound. The Edgerton Highway connects the Richardson Highway with the villages of Lower Tonsina and Chitina. Access to the eastern edge of the quadrangle is provided by dirt roads out of Chitina. The Glenn Highway cuts through the far northwest edge of the quadrangle. The abandoned bed of the Copper River railroad follows the western shore of the Copper River from the southern border of the quadrangle to Chitina. Most of the high, glaciated parts of the study area, however, are only accessible by helicopter.

GEOLOGY

Winkler, Silberman, and others (1981) published the first 1:250,000-scale geologic map of the quadrangle. Plafker, Lull, and others (1989) completed a north-south 1:125,000-scale geological transect across the Valdez quadrangle from Copper Center to Woodworth Glacier. Detailed tectonic (Plafker, Nokleberg, and Lull, 1989) and structural (Nokleberg and others, 1989) studies along this transect provide an integrated model of the geologic history of major rock units in the Valdez quadrangle. Most of the subsequent description of the geology of the quadrangle is derived from these four studies.

The Valdez quadrangle mostly consists of sedimentary and volcanic rocks of the Wrangellia, Peninsular, Chugach, and Prince William terranes (fig. 1). The amalgamated Wrangellia and Peninsular terranes were accreted to the south-central Alaskan margin by mid-Cretaceous time (Hillhouse and Gromme, 1984). To the south of this oceanic arc, subduction assemblages of the Chugach terrane were emplaced between the Early Jurassic and Late Cretaceous (Plafker and others, 1977; Pavlis and Crouse, 1989), and those of the Prince William terrane were emplaced by Eocene time (about 51 Ma) (Plafker, 1987). Following accretion, all terranes were intruded by Eocene felsic to intermediate dikes, sills, and small stocks. Miocene and younger andesitic lavas were extruded in the Wrangellia terrane in the northeast corner of the quadrangle.

The northeast part of the Valdez quadrangle is predominantly underlain by rocks of the Wrangellia terrane. Most of the Wrangellia terrane is east of the Taral fault and north of the Border Ranges fault system (fig. 1). The Chitina fault system divides the Wrangellia terrane into two distinct subterranes (Gardner and others, 1986; Plafker,


147°00′
146°00′
145°00′
144°00′
62°00′
61°00′
Tazlina Lake
COPPER RIVER
Port Valdez
TARAL FAULT
ST. ANNE FAULT
BORDER RANGES FAULT
ICEBERG FAULT
TAZLINA FAULT
SECOND LAKE FAULT
CHITINA FAULT
CONTACT FAULT
Qs
QTw
Km
TKm
Kv
Jbr
Jm
Jc
JPc
JPhc
Mzm
To
g
0 5 10 15 20 25 KILOMETERS

EXPLANATION

- **g** — **Glaciers and superglacial moraine**
- **Qs** — **Surficial deposits, undivided (Quaternary)**

WRANGELLIA TERRANE

- **QTw** — **Wrangell Lava (Holocene to Miocene)**
- **Jc** — **Chitina Valley batholith (Late Jurassic)**
- **JPhc** — **Haley Creek metamorphic assemblage (Late Jurassic and Pennsylvanian and older?)**

PENINSULAR TERRANE

- **Km** — **Matanuska Formation (Cretaceous)**
- **Jbr** — **Border Ranges ultramafic-mafic assemblage (Middle Jurassic)**
- **JTRt** — **Talkeetna Formation (Early Jurassic and Late Triassic?)**

CHUGACH TERRANE

- **TKm** — **Melange (Tertiary or Cretaceous)**
- **Kv** — **Valdez Group (Late Cretaceous)**—Sedimentary and mafic volcanic rocks
- **Mzm** — **McHugh Complex (Mesozoic)**
- **Jm** — **Greenschist and transitional blueschist facies metamorphic rocks (Jurassic or older)**—As mapped includes schist of Liberty Creek and schist of Iceberg Lake

PRINCE WILLIAM TERRANE

- **To** — **Orca Group (Eocene and Paleocene)**—Flyschoid sedimentary and tholeiitic volcanic rocks

- **Contact**
- **Fault**—Dotted where approximately located
- **Thrust fault**—Saw teeth on upper plate. Dotted where approximately located

Figure 2. Generalized geology of the Valdez 1°×3° quadrangle, Alaska. Modified from Winkler, Silberman, and others (1981), Plafker, Lull, and others (1989), Plafker, Nokleberg, and Lull (1989), and Nokleberg and others (1989).

Nokleberg, and Lull, 1989): (1) mainly unmetamorphosed Triassic volcanic and intrusive rocks (hereinafter referred to as the type Wrangellia terrane) in the northeast corner of the quadrangle, and (2) variably metamorphosed upper Paleozoic rocks and associated metaplutonic rocks (hereinafter referred to as the southern Wrangellia terrane margin) south and west of the fault system. Upper Paleozoic mafic volcaniclastic and flow rocks of the Skolai Group, Middle and (or) Late Triassic tholeiitic basalt of the Nikolai Greenstone, and Late Triassic to Middle Jurassic marine evaporitic, calcareous, and argillaceous units compose much of the type Wrangellia terrane (Winkler, Silberman, and others, 1981). Nonmarine conglomerate and marginal-marine sedimentary rocks of Middle Jurassic through Early Cretaceous age crop out in the Kotsina River region. The pre-Cenozoic rocks of the type Wrangellia terrane are unconformably overlain by predominantly andesitic lava flows in the Wrangell Mountains. Most of this extrusive volcanic activity within the Valdez quadrangle is believed to be of Quaternary age, although some could be as old as Miocene (Winkler, Silberman, and others, 1981). South and west of the Chitina fault system, the southern Wrangellia terrane margin is mostly dominated by the Haley Creek metamorphic assemblage of Plafker, Nokleberg, and Lull (1989), which consists of Pennsylvanian and older(?) metasedimentary and metavolcanic rocks and Jurassic and Pennsylvanian metaplutonic rocks (fig. 2). Pavlis and Crouse (1989) suggested that small klippe of these Wrangellia terrane rocks were thrust westward onto rocks of the Valdez Group during late Mesozoic strike-slip movement along the Border Ranges fault system. Also, prior to accretion onto the Alaskan continental margin, Late Jurassic quartz monzodiorite and lesser amounts of quartz diorite, granodiorite, and tonalite (the Chitina Valley batholith of MacKevett, 1978) intruded sedimentary and volcanic rocks of the Wrangellia terrane, especially the southern Wrangellia terrane margin. These deformed intrusive rocks are part of the Tonsina-Chichagof plutonic belt of Hudson (1983).

The northwestern and north-central parts of the study area consist of rocks of the Peninsular terrane (fig. 1) that are overlain by unconsolidated Quaternary sediments throughout much of the Copper River Lowlands. Jurassic and older (?) mafic and ultramafic plutonic rocks of the Border Ranges ultramafic-mafic assemblage (Plafker, Nokleberg, and Lull, 1989) extend across the entire southern part of the Peninsular terrane, from the Taral fault, along its eastern boundary, westward into the Anchorage quadrangle (fig. 2). Layered gabbronorite and scattered ultramafic bodies make up most of the Border Ranges ultramafic-mafic assemblage within the study area. The assemblage is commonly divided into the relatively deeper level Tonsina ultramafic-mafic sequence (Plafker, Nokleberg, and Lull, 1989; see also Coleman and Burns, 1985; DeBari and Coleman, 1989) to the east of the Richardson highway and the Nelchina River Gabbronorite (Plafker, Nokleberg, and Lull, 1989; Burns, in press), which extends to the west from the highway. A klippe of the Peninsular terrane on rocks of the Valdez Group, between the Tazlina and Nelchina Glaciers, contains Jurassic amphibolite, orthogneiss, and layered quartz gabbro likely derived, in part, from the Nelchina River Gabbronorite. Andesitic and basaltic tuff, breccia, flows, and volcaniclastic rocks of the Triassic(?) and Jurassic Talkeetna Formation are north of the belt of mafic and ultramafic rocks. Rocks of the Talkeetna Formation are intruded by widespread bodies of Jurassic intermediate plutonic rocks. Cretaceous marine clastic sedimentary rocks of the Matanuska Formation crop out in the extreme northwest corner of the quadrangle.

The Border Ranges fault system separates the Wrangellia and Peninsular terranes from the Chugach terrane to the south (fig. 1). Rocks of the Chugach terrane make up most of the southern two-thirds of the Valdez quadrangle. In the east-central part of the quadrangle, Middle Jurassic or older rocks of the informally named schist of Liberty Creek are between the Border Ranges and Second Lake faults (fig. 2). This approximately 30-km-long belt of ductilely deformed greenschist and subordinate blueschist has both mafic volcanic and pelitic sedimentary rock protoliths. Rocks of the Upper Triassic to mid-Cretaceous McHugh Complex crop out south of the Second Lake and Border Ranges faults and north of the Tazlina fault. This locally structurally chaotic melange of oceanic rocks is composed of mafic volcanic units and lesser pelitic sediments, chert, and carbonate units. Rocks of the McHugh Complex are generally metamorphosed to prehnite-pumpellyite facies. Most of the Chugach terrane is composed of rocks of the Upper Cretaceous Valdez Group, which is dominated by highly deformed, greenschist facies marine argillite, siltstone, sandstone, and conglomeratic sandstone. Tholeiitic basalt, pillow basalt, and mafic metatuff are commonly interbedded with marine sedimentary rocks along the southern edge of the Valdez quadrangle. In places, the metavolcanic rocks contain disseminations and lenses of pyrite, pyrrhotite, chalcopyrite, cubanite, and sphalerite (Winkler, Silberman, and others, 1981). Tertiary felsic to intermediate dikes, sills, and plugs intrude much of the Valdez Group.

Rocks of the Tertiary Orca Group of the Prince William terrane are thrusted beneath and accreted to rocks of the Valdez Group along the Contact fault system in the southwest corner of the Valdez quadrangle (fig. 1). The Orca Group is predominantly marine argillite siltstone, sandstone, and conglomerate, metamorphosed to low metamorphic grades. On the west side of Valdez Arm, tholeiitic basalt, pillow breccia, and minor tuff are interbedded with the flysch facies.

KNOWN MINERAL RESOURCES

Mineral occurrences in the Valdez quadrangle have been tabulated by Cobb and Matson (1972), MacKevett and Holloway (1977), Cobb (1979), and Winkler, Miller, and others (1981). Detailed descriptions of occurrences in the southern part of the quadrangle are included in Jansons and others (1984). Significant occurrences are summarized in figure 3.

Mesothermal lode gold deposits of the Port Valdez district are widespread between Columbia and Valdez Glaciers on the north side of Port Valdez (fig. 3). Gold-bearing veins in the district have yielded slightly more than 1,860,000 g of gold, mostly from the Cliff mine (fig. 3, loc. 1), which has been the most productive gold lode in the Kenai-Chugach Mountains (Nelson and others, 1984). Ore minerals in quartz veins within the district include electrum, pyrite, arsenopyrite, galena, sphalerite, and chalcopyrite and lesser tetrahedrite, pyrrhotite, and stibnite. Most veins cut metasedimentary rocks of the Valdez Group (Brooks, 1912), although in a few places they also cut small felsic dikes and stocks (Johnson, 1915; Pickthorn, 1982). Pickthorn (1982) and Pickthorn and Silberman (1984) suggested that auriferous veins in the Port Valdez district formed from a mixing of meteoric and metamorphic waters, and believed that deposition was from a boiling fluid. Goldfarb and others (1986), however, hypothesized that veins formed from a solely metamorphic fluid produced during prograde devolatilization of deeply buried rocks of the Valdez Group or Orca Group.

South of Port Valdez, a number of small gold-bearing quartz veins cut graywacke and slate of the Valdez Group on the south side of Jack Bay (fig. 3, locs. 2, 3) (Johnson, 1919). These veins were noted to contain gold, pyrite, pyrrhotite, and arsenopyrite.

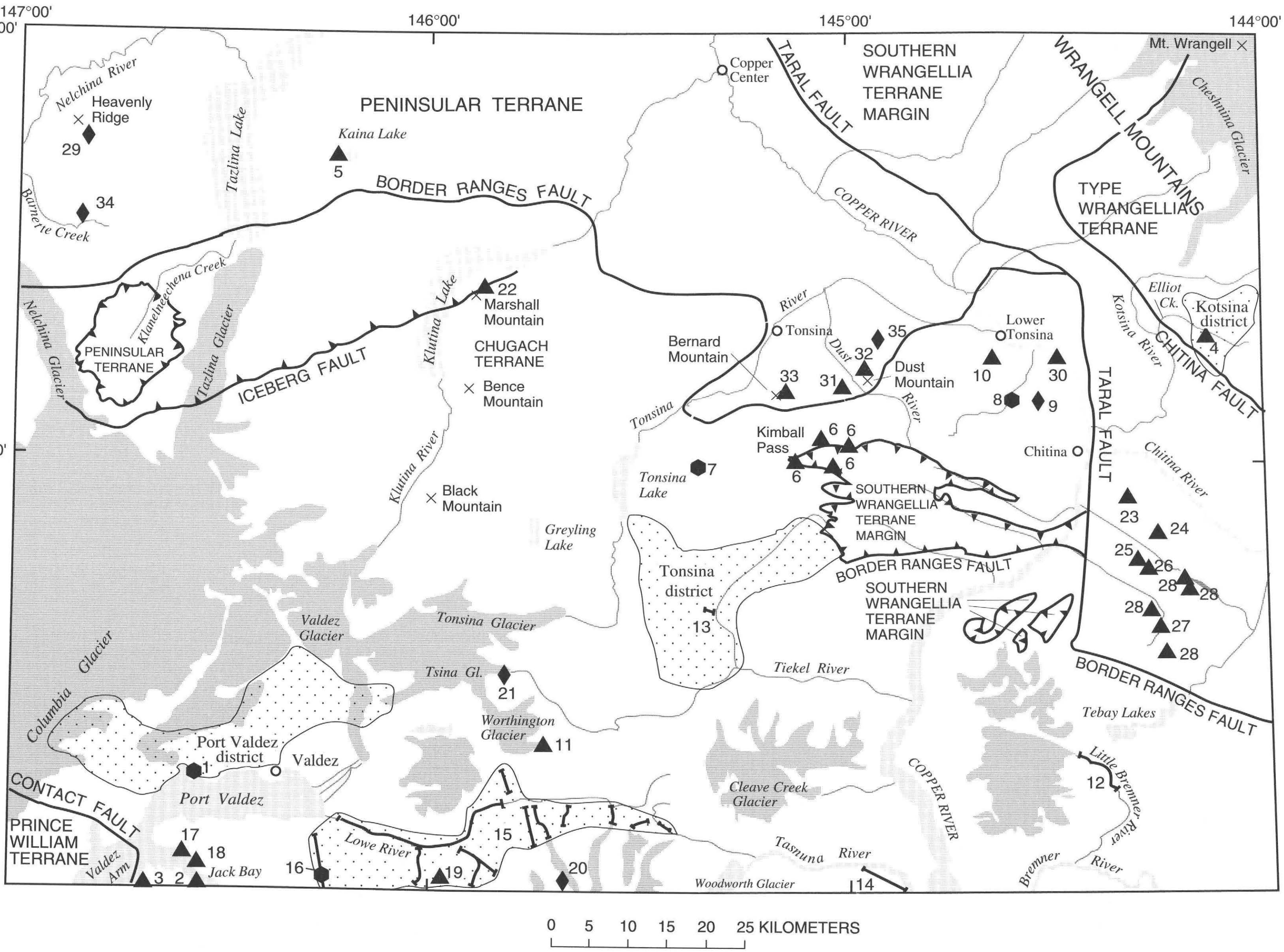
Gold-bearing quartz veins of the Tonsina district (fig. 3) crop out in the Chugach Mountains between the headwaters of the Tonsina and Tiekel Rivers (Moffit, 1935). The veins are within metasedimentary rocks of the Valdez Group and contain gold, galena, sphalerite, arsenopyrite, and chalcopyrite. Most auriferous veins show a spatial association with parallel northerly striking felsic dikes (Moffit, 1935).

Gold-bearing quartz veins are also reported from other locations in many of the lithologies of the Valdez quadrangle. To the northeast, gold-bearing quartz veins cut Permian metavolcanic rocks and gabbro at Benito Creek (fig. 3, loc. 4) in the Kotsina River valley (Moffit and Mertie, 1923). Gold lodes are present along the contact between rocks of the Talkeetna Formation and granodiorite near Kaina Lake (fig. 3, loc. 5) in the northwest part of the quadrangle (Winkler, Miller, and others, 1981). In the center of the quadrangle, a few gold-bearing veins are described from the Kimball Pass area (fig. 3, loc. 6) (Winkler, Miller, and others, 1981), from Quartz Creek (fig. 3, loc. 7) (Moffit, 1918) 5–10 km north of the Tonsina district veins, and cutting metamorphic and igneous rocks to the west and northwest of Chitina (fig. 3, locs. 8–10) (Berg and Cobb, 1967; MacKevett and Holloway, 1977). Mineralized veins cut rocks of the Valdez Group near Worthington Glacier (fig. 3, loc. 11) in the south-central part of the quadrangle (Winkler, Miller, and others, 1981).

Placer gold production from the Port Valdez district has been negligible. Minor amounts of gold may have been recovered from the Little Bremner River (fig. 3, loc. 12) (Moffit, 1914) and from Boulder Creek (fig. 3, loc. 13) (Moffit, 1935) in the Tonsina district. MacKevett and Holloway (1977) and Winkler, Miller, and others (1981) listed known placer gold prospects from the Valdez quadrangle. The majority of these are near known auriferous lodes in the Tonsina and Port Valdez districts and within the Lowe and Tiekel River watersheds. Jansons and others (1984) assessed the placer gold potential of much of the Lowe and Tasnuna River basins along the southern edge of the Valdez quadrangle. The more significant placer showings include samples from the Tasnuna River, Marshall Glacier, Sulfide Gulch, Solomon Gulch, Mineral Creek, Brown Creek, and Lowe River (fig. 3, locs. 14, 15).

Copper-rich volcanogenic massive and disseminated sulfide occurrences are associated with mafic volcanic rocks of the Valdez Group along the southern edge of the Valdez quadrangle and elsewhere in the Prince William Sound area (Mendenhall, 1900; Schrader, 1900; Grant and Higgins, 1910; Wiltse, 1973; Nelson and others, 1984). These include the Midas mine (fig. 3, loc. 16) (Johnson, 1919; Moffit and Fellows, 1950; Rose, 1965), about 12 km south of Valdez. The mineralogy of the Midas mine and the restriction of the mineral deposit to sedimentary rocks near volcanic piles suggest that this is a Besshi-type massive sulfide (Steve Nelson, U.S. Geological Survey, written commun., 1986; Crowe and others, 1992). Ore at the Midas mine, hosted by black slate and less commonly by graywacke, consists of pyrite and subordinate pyrrhotite, chalcopyrite, and sphalerite. The Midas mine produced about 1,544 metric tons of copper, making it the fourth largest copper producer in the Prince William Sound region, and it is estimated to contain additional reserves of 56,234 metric tons of 1.6 percent Cu (Nelson and others, 1984). Ore shipments also contained between 7.81–13.13 grams per metric ton Ag and 1.56–1.94 grams per metric ton Au (Rose, 1965).

A few other zones rich in iron and copper sulfide minerals, within metasedimentary rocks of the Valdez Group, are near greenstone in the southwest part of the Valdez quadrangle. Along the north shore of Jack Bay, pyrite, pyrrhotite, chalcopyrite, sphalerite, arsenopyrite, and galena


147°00'
146°00'
145°00'
144°00'
62°00'
61°30'
61°00'
PENINSULAR TERRANE
Heavenly Ridge
Nelchina River
Tazlina Lake
Kaina Lake
Barnette Creek
BORDER RANGES FAULT
Copper Center
TARAL FAULT
SOUTHERN WRANGELLIA TERRANE MARGIN
WRANGELL MOUNTAINS
Mt. Wrangell
Cheshnina Glacier
TYPE WRANGELLIA TERRANE
COPPER RIVER
Klanelneechena Creek
Nelchina Glacier
PENINSULAR TERRANE
Tazlina Glacier
ICEBERG FAULT
Klutina Lake
Marshall Mountain
CHUGACH TERRANE
Bence Mountain
Klutina River
Black Mountain
Greyling Lake
Bernard Mountain
Tonsina
Tonsina River
Dust River
Dust Mountain
Lower Tonsina
Elliot Ck.
Kotsina district
Kotsina River
CHITINA FAULT
Kimball Pass
Tonsina Lake
Chitina
Chitina River
SOUTHERN WRANGELLIA TERRANE MARGIN
Tonsina district
BORDER RANGES FAULT
SOUTHERN WRANGELLIA TERRANE MARGIN
Valdez Glacier
Tonsina Glacier
Tiekel River
Columbia Glacier
Tsina Gl.
Worthington Glacier
Tebay Lakes
Port Valdez district
Valdez
Port Valdez
CONTACT FAULT
PRINCE WILLIAM TERRANE
Valdez Arm
Jack Bay
Lowe River
Cleave Creek Glacier
COPPER RIVER
Tasnuna River
Woodworth Glacier
Little Bremner River
Bremner River
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
0 5 10 15 20 25 KILOMETERS

EXPLANATION

- **Mine**—Identified by number
- **Prospect**—Identified by number
- **Occurrence**—Identified by number
- **Placer**—Identified by number
- **Mining district**—Area includes numerous mines and prospects
- **Glacier or icefield**
- **Fault**—Approximately located
- **Thrust fault**—Approximately located. Saw teeth on upper plate

Mines, prospects, and occurrences

1. Cliff mine
2. Orion prospect
3. Curly-Kidney prospect
4. Benito Creek prospect
5. Kaina Lake prospect
6. Kimball Pass prospects
7. Quartz Creek mine
8. Opal mine
9. Fivemile Creek occurrence
10. Hundell Creek prospect
11. Worthington Glacier prospect
12. Little Bremner River placer
13. Boulder Creek placer
14. Tasnuna River placer
15. Unnamed placers
16. Midas mine
17. Jack Bay copper prospect
18. Jack Bay prospect
19. Addison-Powell prospect
20. Wortmann Glacier occurrence
21. Tsina Glacier occurrence
22. Marshall Mountain prospect
23. Blackney prospect
24. Surprise prospect
25. Divide Creek prospect
26. Falls Creek prospect
27. Spirit Mountain prospect
28. Summit Lake prospects
29. Heavenly Ridge occurrence
30. Liberty Falls prospect
31. Sheep Hill prospect
32. Dust Mountain prospect
33. Bernard Mountain prospect
34. Barnette Creek occurrence
35. Scarp occurrence

Figure 3. Metallic mines, prospects, and occurrences recognized within the Valdez 1°×3° quadrangle, Alaska. These mostly consist of small gold-bearing quartz veins. They also include placer gold; copper sulfide-dominant volcanogenic, magmatic, and Kennecott-type; and podiform chromite mines, prospects and (or) occurrences.

are disseminated in metasedimentary rocks near greenstone and along shear zones (fig. 3, locs. 17, 18) (Moffit and Fellows, 1950). The Addison-Powell prospect (fig. 3, loc. 19), probably near the terminus of the glacier in the West Fork of Sulphide Gulch (Rose, 1965), was reported to contain chalcopyrite as the principal ore mineral (Johnson, 1918). Numerous greenstone sills and disseminated pyrite and pyrrhotite are present within the slate in this area (Rose, 1965). Volcanogenic copper-rich mineral occurrences adjacent to Wortmann Glacier (fig. 3, loc. 20) (Winkler, Miller, and other, 1981) are also spatially associated with discordant polymetallic quartz veins. Farther to the north, metavolcanic rocks of the Valdez Group near Tsina Glacier (fig. 3, loc. 21) and of the McHugh Complex at Marshall Mountain (fig. 3, loc. 22) contain similar massive and (or) disseminated mineral occurrences (Winkler, Miller, others, 1981).

Southeast of Chitina, within the southern Wrangellia terrane margin and north of the Tebay fault, four copper prospects (fig. 3, locs. 23–26) are hosted in late Paleozoic mafic volcanic rocks (Moffit, 1914). Pyrite, chalcopyrite, chrysocolla, chalcocite, bornite, covellite, and (or) malachite are present as disseminations and within veins. Winkler, Miller, and others (1981) hypothesized that the disseminated mineral occurrences reflect submarine volcanism; later hydrothermal activity remobilized some of the copper into faults and fractures.

Massive and disseminated iron-copper-nickel sulfide minerals of probable magmatic origin are hosted by peridotite and pyroxenite sills that intrude metasedimentary rocks of the southern Wrangellia terrane margin immediately to the south of the Tebay fault (fig. 3, locs. 27, 28) (Herreid, 1970). Ore minerals include bravoite, pentlandite, pyrrhotite, chalcopyrite, pyrite, and sphalerite. Reserve estimates include 5,900 metric tons of ore grading from 0.22 to 7.61 percent Ni and from 0.12 to 1.56 percent Cu. Minor silver, gold, and platinum-group-element enrichments are reported from ore samples (Foley and others, 1989).

Numerous copper occurrences are in the headwater areas of the Kotsina River and along Elliot Creek in the Kotsina mining district (fig. 3) in the northeast part of the Valdez quadrangle. Mineral occurrences are predominantly veins in shear zones and brecciated fractures within greenstone and adjacent limestone of the Wrangellia terrane (Moffit and Mertie, 1923). Ore minerals include pyrite, chalcopyrite, bornite, malachite, azurite, chalcanthite, covellite, tetrahedrite, and enargite and anomalous traces of silver and gold.

Most of these occurrences in the northeast part of the study area are probably hydrothermal vein systems related to Late Jurassic or Tertiary plutonism (Winkler, Miller, others, 1981). A few may contain metals leached from the subaerial volcanic rocks and perhaps can be classified as sabkha-related, Kennecott-type copper systems (Winkler, Miller, and others, 1981). The geology and mineralogy of these latter occurrences suggest that they are similar in origin to large orebodies 60 km to the west at Kennecott. These Kennecott deposits have been Alaska's largest producer of copper, yielding 540,000 metric tons of copper and 2.8 billion grams of silver between 1913 and 1938 (MacKevett, 1976). Irregular, massive bodies of mostly chalcocite have replaced pre-existing bornite in limestone of the Wrangellia terrane, generally within 100 m of underlying greenstone. Armstrong and MacKevett (1977) hypothesized that the initial bornite-rich ore was deposited by oxygenated ground water that leached copper from the Nikolai Greenstone and deposited it in an overlying, reducing sabkha environment.

Pyrite-rich volcanic rocks of the Talkeetna Formation crop out at Heavenly Ridge (fig. 3, loc. 29) in the Valdez quadrangle and at a number of locations in the adjacent Anchorage quadrangle (Newberry, 1986). Andesite and dacite at Heavenly Ridge are strongly silicified, and mafic minerals are altered to an epidote-chlorite-calcite-pyrite-sphene assemblage. Selected samples contain 3–15 percent pyrite and as much as 0.2 ppm Ag (Newberry, 1986).

Lenses of manganite (MnO[OH]) are in greenstone units of the schist of Liberty Creek (fig. 3, loc. 30), a few kilometers southeast of the village of Lower Tonsina (Berg and Cobb, 1967; Jasper, 1967). The largest lens is about 12 m long and as wide as 60 cm.

Lenses and disseminations of chromite are within dunite of the Tonsina ultramafic-mafic sequence at Sheep Hill, Dust Mountain, and Bernard Mountain (fig. 3, locs. 31–33) (Hoffman, 1974; Burns, 1985). Three exposed deposits at Bernard Mountain contain 311,000 metric tons of Cr_2O_3, and one at Sheep Hill contains 23,500 metric tons of Cr_2O_3 (Foley and Barker, 1985). Chrome spinels in the dunite and peridotite at these locations contain anomalous amounts of the platinum-group elements (Foley and others, 1987). One such spinel-rich segregation from malachite-stained dunite at Dust Mountain contains 10.5 ppm Pd and 7.9 ppm Pt. The platinum-group element contents of chromite concentrates are as great as 3.4 ppm at Dust Mountain, 1.0 ppm at Sheep Hill, and 1.7 ppm at Bernard Mountain. Chromian spinel bands in clinopyroxenite also contain as much as 610 ppb Au (Foley and others, 1987).

Magmatic-sulfide prospects are in gabbroic rocks in the Barnette Creek area (fig. 3, loc. 34) and near the benchmark "Scarp" (fig. 3, loc. 35) (Newberry, 1986). In the Barnette Creek area, in the Nelchina River Gabbronorite, disseminated and irregular masses of chalcopyrite, pyrrhotite, and lesser pentlandite are exposed in a zone 10 cm thick by 3 m long within layered spinel gabbronorite. At the Scarp occurrence, in the Tonsina ultramafic-mafic sequence, Newberry (1986) reported as much as 5 percent pyrite and lesser marcasite and chalcopyrite. Detailed investigations of the gabbroic rocks near Nelchina Glacier, a few kilometers to the west in the Anchorage quadrangle, show that the ultramafic belt of rocks has little potential for iron, titanium, or vanadium resources (Newberry, 1986).

AMRAP GEOCHEMICAL SURVEY

GEOCHEMICAL METHOD

This report primarily describes results of the interpretation of analyses of 606 stream-sediment and 453 heavy-mineral-concentrate samples collected as part of AMRAP during 1978 and 1979. Analytical results for these samples are presented in Miller and others (1982). Stream-sediment samples (–80-mesh) were generally collected from first- or second-order active stream channels; however, in areas of active glaciation, some of the sediment samples were collected on medial or lateral moraines. For simplicity, the moraine-sediment samples are included with the discussion of the AMRAP stream-sediment samples throughout the remainder of the text. At most sites, heavy-mineral-concentrate samples were also collected by panning about 7–10 kg of sediment using a standard 35-cm gold pan. Density of sediment sampling was about 1 site per 10–20 km^2 throughout much of the Chugach and Wrangell Mountains (Miller and others, 1982, pl. 1); however, few samples were collected from the rugged, heavily glaciated peaks of the Chugach Mountains in the western part of the Valdez quadrangle or from the Copper River Lowlands in the north-central part of the quadrangle.

Stream- and moraine-sediment samples were oven-dried and ground to –150-mesh prior to chemical analysis. Air-dried concentrate samples were sieved to –20-mesh, passed through bromoform (specific gravity 2.86) to remove any remaining lightweight material, and passed under a hand magnet to remove any strongly magnetic minerals. The remaining concentrate was ground to –150-mesh prior to chemical analysis. Microscopic examination of concentrate samples was not undertaken.

All sediment and concentrate samples were analyzed semiquantitatively for 30 elements using a direct current-arc optical emission spectrograph according to the methods outlined by Grimes and Marranzino (1968). Sediment samples were also analyzed by atomic absorption spectrometry for gold, copper, and zinc and concentrates for gold and zinc, as described by Ward and others (1969) (denoted as AA-Au, AA-Cu, and AA-Zn in following discussion). Hot nitric acid, used for sample decomposition prior to copper and zinc analyses, breaks down most mineral phases except silicates. Therefore, atomic absorption analyses of samples for copper and zinc reflect non-silicate-bound contributions.

A total of 448 bedrock samples were also collected from the Valdez quadrangle (Miller and others, 1982). Unmineralized samples were collected to determine background levels for many elements, and altered or mineralized rocks were collected to help determine geochemical signatures reflecting hydrothermal activity. Rock samples were crushed and sieved to –80-mesh. They generally were analyzed by chemical methods similar to those described above for stream-sediment samples.

STATISTICAL METHOD

Univariate statistics for the sediment and concentrate samples from the AMRAP survey are shown in tables 1 and 2. Detection ratios, the number of unqualified results divided by the total number of analytical results, are also given in tables 1 and 2. Univariate statistics were not computed for highly censored elements (detection ratios less than 0.50). Cohen's (1959) maximum-likelihood method was used to approximate the geometric mean and geometric deviation for censored data for elements having detection ratios greater than 0.50. Minimum, median, 90th percentile, 95th percentile, 98th percentile, and maximum values are tabulated to present the range in the geochemical data.

Generally using spectrographic intervals for class width, histograms for most elements are shown in figures 4 and 5. Histograms were not produced for elements for which data are highly censored. The histograms conveniently show the range of the data, modes for each element, and the general form of the density distribution. The expected range for 95 percent of all values in the lognormal distribution (Miesch, 1976) is included for each element (tables 1, 2).

Anomalous element values are those that deviate from the norm or exceed some geochemical background value. Commonly for geochemical data, the 95th percentile for a given geochemical distribution (tables 1, 2) is chosen as a threshold, and all values greater than the threshold are considered anomalous. For many elements, however, inspection of the histograms (figs. 4, 5) indicates that the thresholds should be adjusted from the 95th percentile to accommodate distinct breaks in the frequency distribution of the data. The resulting thresholds for ore-related elements are listed in table 3.

R-mode factor analysis with Varimax rotation was used to identify the dominant geochemical associations in both data sets. The majority of the data, because they were determined by six-step semiquantitative emission spectrography, represent the midpoints of equal logarithmic class widths. Therefore, data sets were log transformed prior to factor analysis, and the more highly censored elements were removed from each data set. Because of their

Table 1. Univariate statistical estimates for 606 stream-sediment samples, Valdez 1°×3° quadrangle, Alaska.

[All values for lower determination limit, minimum, median, percentiles, maximum, geometric mean and deviation, and expected range are in parts per million, except for values for Fe, Mg, Ca, and Ti, which are in percent. Most elements were determined by semiquantitative emission spectroscopy. AA-Au, AA-Cu, and AA-Zn are atomic absorption analyses. Samples were also analyzed for Au, Bi, Cd, Nb, Sb, Sn, W, and Th by emission spectroscopy; all data for these elements were below the lower determination limit. Detection ratio is number of uncensored concentrations divided by total number of samples analyzed for a given element. N is number of samples in which concentrations could not be detected at lower determination limit; L is number of samples in which concentrations were reported as observable but were less than lower determination limit; G is number of samples in which concentrations were reported as observable but were greater than upper determination limit; B is number of samples in which concentrations were not measured. Concentration values qualified with an N, L, or G indicate lower or upper determination limits. Geometric mean and geometric deviation were calculated using Cohen's (1959) maximum-likelihood method for censored distributions. Expected range is the distribution of 95 percent of all data expected for lognormal data (Miesch, 1976)]

Element	Detection ratio	N	L	G	B	Minimum value	Median value	90th percentile	95th percentile	98th percentile	Maximum value	Geometric Mean	Geometric Deviation	Expected range
Fe	1.0	0	0	0	0	1	7	15	15	15	20	6.4	1.9	1.8–23
Mg	1.0	0	0	0	0	0.2	2	5	5	7	10	2.1	1.7	0.7–6.1
Ca	1.0	0	0	0	0	0.1	1	5	7	7	20	1.3	2.4	0.2–7.5
Ti	1.0	0	0	0	0	0.15	0.5	1	1	1	3	0.6	1.4	0.3–1.1
Mn	1.0	0	0	0	0	150	1,000	2,000	2,000	2,000	3,000	1,160	1.7	400–3,400
Ag	0.01	602	3	0	0	0.5N	0.5N	0.5N	0.5N	0.5N	5	--	--	--
As	0	605	1	0	0	200N	200N	200N	200N	200N	200L	--	--	--
B	0.99	0	3	0	0	10L	100	200	300	500	1,000	87	2.3	16–460
Ba	0.99	1	1	0	0	20N	1,000	1,500	2,000	2,000	3,000	86	2.3	16–450
Be	0.66	63	145	0	0	1N	1	1	1	1.5	2	0.9	1.2	0.6–1.3
Co	1.0	0	0	0	0	10	50	70	100	100	150	34	2.0	9–140
Cr	0.99	0	0	1	0	20	150	500	500	700	5,000G	170	2.0	43–680
Cu	1.0	0	0	0	0	10	100	200	200	200	300	89	1.9	25–320
La	0.97	18	1	0	0	20N	50	50	70	70	70	49	1.2	34–71
Mo	0.01	599	2	0	0	5N	5N	5N	5N	5N	50	--	--	--
Ni	1.0	0	0	0	0	10	100	150	150	200	1,000	76	1.8	23–250
Pb	0.94	6	28	0	0	10N	20	50	70	100	100	20	1.9	6–72
Sc	1.0	0	0	0	0	7	20	50	50	100	150	25	1.6	10–64
Sr	1.0	0	0	0	0	100	300	700	1,000	1,000	1,500	340	1.7	120–980
V	1.0	0	0	0	0	50	300	500	1,000	1,000	1,500	260	1.8	80–840
Y	0.99	0	4	0	0	10L	30	50	50	70	70	32	1.6	13–82
Zn	0.02	378	218	0	0	200N	200N	200L	200L	200L	200	--	--	--
Zr	0.99	0	5	0	0	10L	150	200	300	300	1,000	120	2.0	30–480
AA-Au	0.12	452	82	0	4	0.05N	0.05N	0.05	0.10	0.20	1.5	--	--	--
AA-Cu	1.0	0	0	0	0	5	50	100	100	150	300	47	1.7	16–140
AA-Zn	1.0	0	0	0	0	5	100	150	150	200	200	77	1.8	24–250

Table 2. Univariate statistical estimates for 453 nonmagnetic heavy-mineral-concentrate samples, Valdez 1°×3° quadrangle, Alaska.

[All values for lower determination limit, minimum, median, percentiles, maximum, geometric mean and deviation, and expected range are in parts per million, except for values for Fe, Mg, Ca, and Ti, which are in percent. Most elements were determined by semiquantitative emission spectroscopy. AA-Au and AA-Zn are atomic absorption analyses. Samples were also analyzed for Bi, Cd, Sb, Sn, and Th by emission spectroscopy; all data for these elements were below the lower determination limit. Detection ratio is number of uncensored concentrations. N is number of samples in which concentrations could not be detected at lower determination limit; L is number of samples in which concentrations were reported as observable but were less than lower determination limit; G is number of samples in which concentrations were reported as observable but were greater than upper determination limit; B is number of samples in which concentrations were not measured. Concentration values qualified with an N, L, or G indicate lower or upper determination limits. Geometric mean and geometric deviation were calculated using Cohen's (1959) maximum-likelihood method for censored distributions. Expected range is the distribution of 95 percent of all data expected for lognormal data (Miesch, 1976)]

Element	Detection ratio	N	L	G	B	Minimum value	Median value	90th percentile	95th percentile	98th percentile	Maximum value	Geometric Mean	Geometric Deviation	Expected range
Fe	0.99	0	0	1	0	5	10	20	20	20	20G	12	1.4	6.1–24
Mg	1.0	0	0	0	0	0.3	3	5	7	7	10	2.9	1.7	1.0–8.4
Ca	1.0	0	0	0	0	0.5	3	7	10	10	10	3.5	1.9	1.0–13
Ti	0.57	0	0	195	0	0.1	1	2G	2G	2G	2G	1.1	1.9	0.3–4
Mn	0.97	0	0	13	0	500	1,500	3,000	5,000	5,000G	5,000G	1,800	1.5	800–4,100
Ag	0.12	387	12	0	0	1N	1N	3	5	7	30	--	--	--
As	0.03	429	9	0	0	500N	500N	500N	500L	500	2,000	--	--	--
Au	0	429	22	0	0	20N	20N	20N	20L	20L	30	--	--	--
B	0.99	0	1	0	0	20L	100	300	500	500	1,500	110	2.4	19–630
Ba	0.92	0	30	3	0	50L	700	1,500	1,500	2,000	5,000G	470	3.3	43–5,100
Be	0.14	159	233	0	0	2N	2L	2	2	2	3	--	--	--
Co	1.0	0	0	0	0	15	50	70	100	100	300	53	1.5	24–120
Cr	1.0	0	0	0	0	50	500	700	1,000	1,000	2,000	350	1.9	97–1,300
Cu	1.0	0	0	0	0	20	200	700	700	1,000	10,000	190	2.3	36–1,000
La	0.89	13	38	1	0	50N	100	300	500	500	1,000G	95	2.5	15–590
Mo	0.04	422	15	0	0	10N	10N	10N	10L	15	70	--	--	--
Nb	0.01	20	429	0	0	50N	50L	50L	50L	50L	100	--	--	--
Ni	1.0	0	0	0	1	20	100	200	300	300	700	110	1.7	38–320
Pb	0.70	12	125	0	0	20N	30	200	500	700	7,000	38	4.5	2–770
Sc	1.0	0	0	0	0	20	50	100	100	100	100	59	1.4	30–120
Sr	0.95	8	15	0	0	200N	500	1,000	1,500	1,500	2,000	490	2.0	120–2,000
V	1.0	0	0	0	0	100	300	500	500	500	700	300	1.3	180–510
W	0.02	435	10	0	0	100N	100N	100N	100N	100L	500	--	--	--
Y	0.95	9	12	0	0	20N	70	150	200	200	300	64	2.1	15–280
Zn	0.01	429	18	0	0	500N	500N	500N	500L	500L	1,000	--	--	--
Zr	0.78	0	5	96	0	20L	300	1,000G	1,000G	1,000G	1,000G	350	4.4	18–3,600
AA-Au	0.31	241	64	0	10	0.01N	0.01N	1.0	3.0	15	100	--	--	--
AA-Zn	0.96	8	4	0	126	20N	100	200	200	300	2,000	92	2.1	21–410

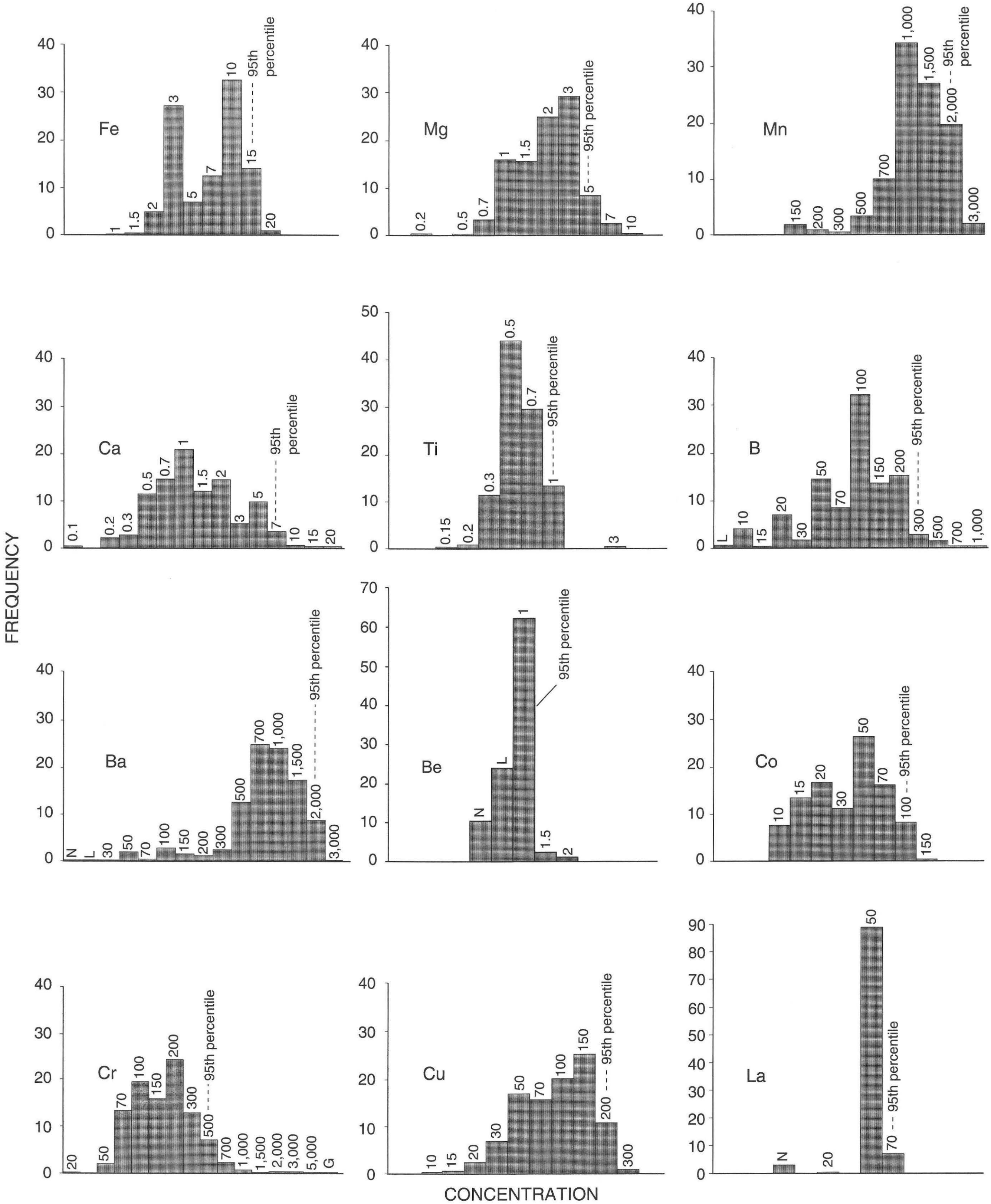
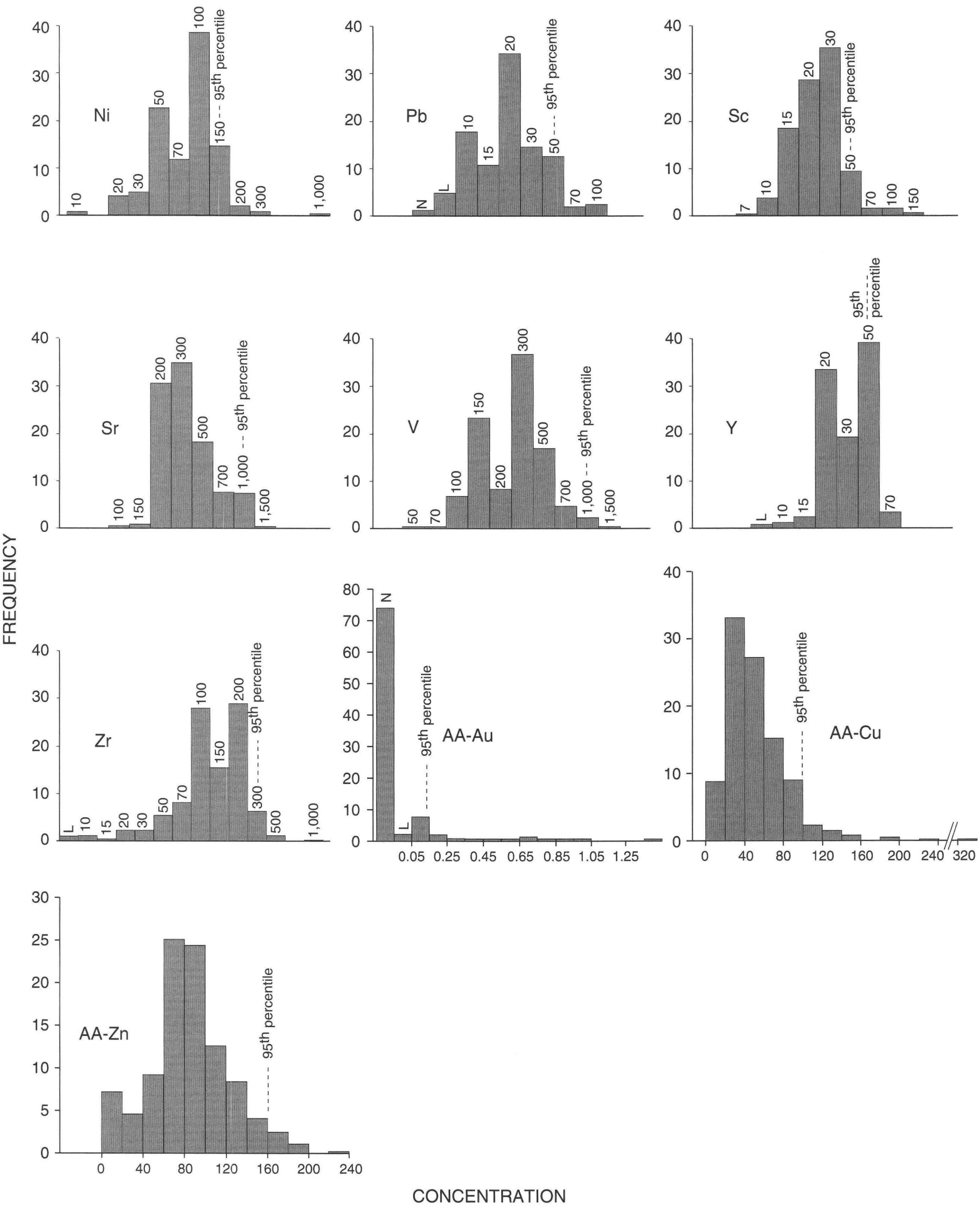
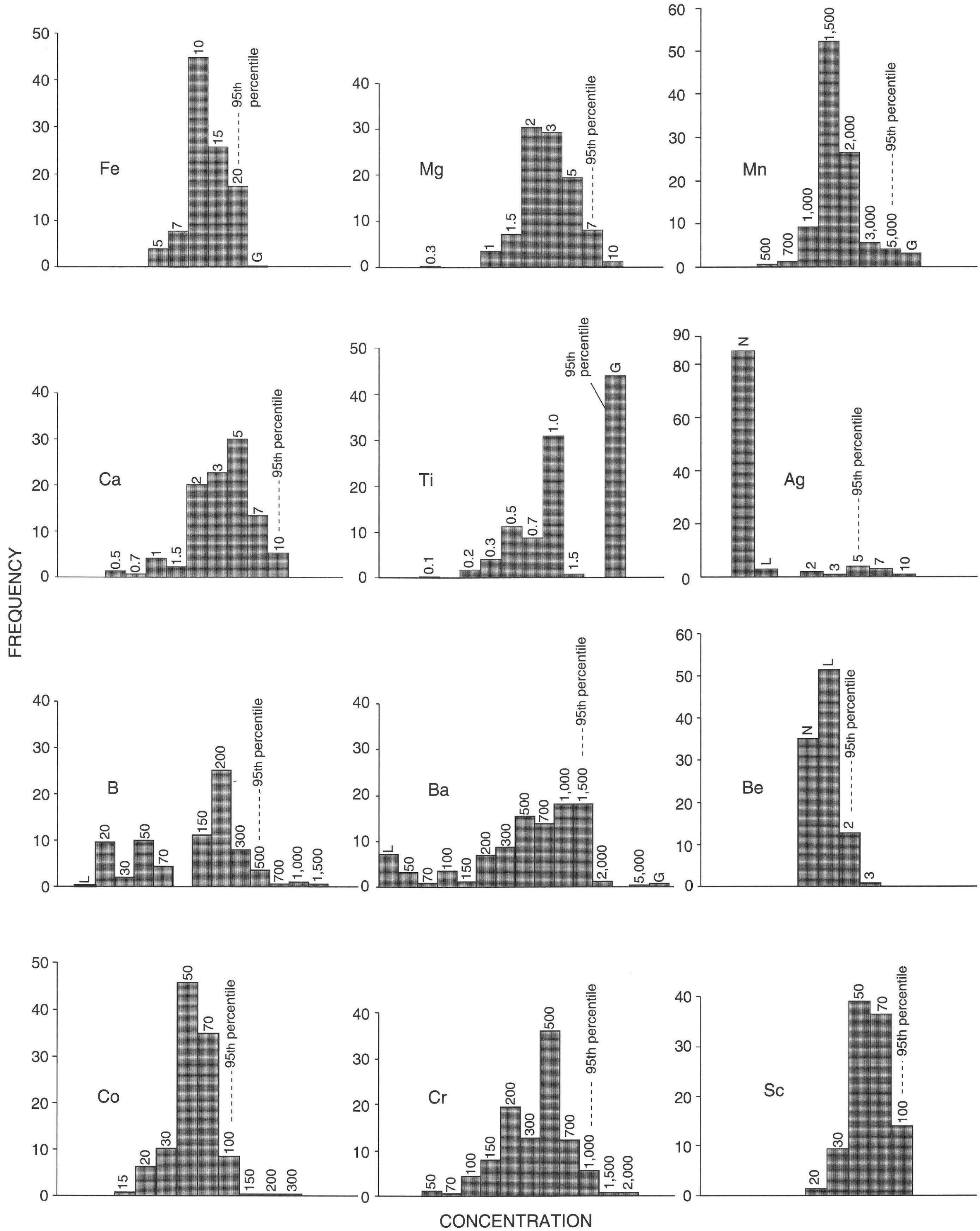


Figure 4 (above and facing page). Histograms showing the density distribution for selected elements from the chemical analyses of 606 stream-sediment samples, Valdez 1°×3° quadrangle, Alaska. All concentrations are in parts per million, except for Fe, Mg, Ca, and Ti, which are in percent. N, L, and G refer to samples in which concentrations could not be detected at the lower determination limit, were reported as observable but were less than the lower determination limit, and were reported as observable but were greater than the upper determination limit, respectively.


Ni
95th percentile
Pb
95th percentile
Sc
95th percentile
Sr
95th percentile
V
95th percentile
Y
95th percentile
Zr
95th percentile
AA-Au
95th percentile
AA-Cu
95th percentile
AA-Zn
95th percentile
FREQUENCY
CONCENTRATION


Fe
Mg
Mn
Ca
Ti
Ag
B
Ba
Be
Co
Cr
Sc
95th percentile
FREQUENCY
CONCENTRATION

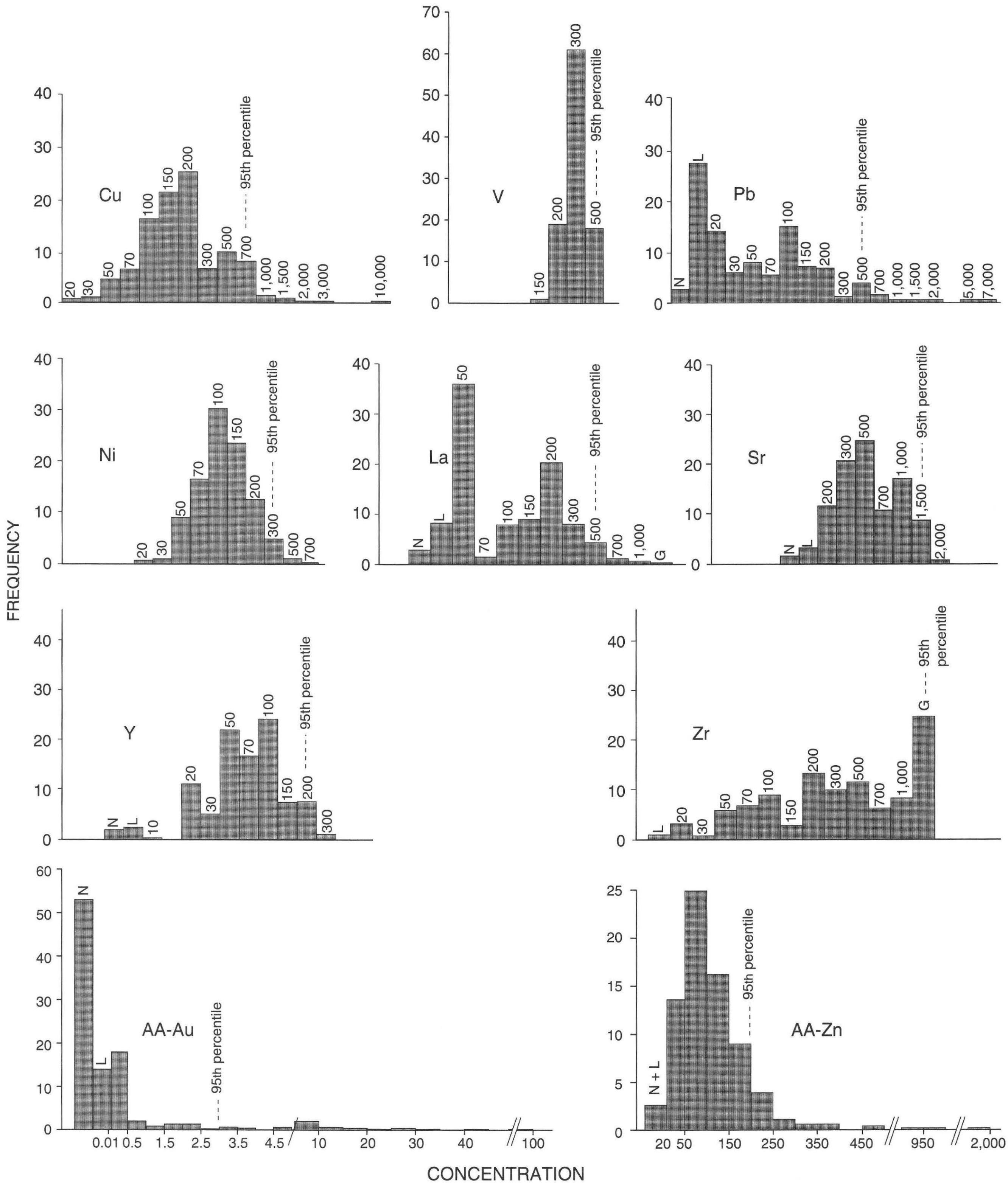


Figure 5 (above and facing page). Histograms showing the density distribution for selected elements from the chemical analyses of 453 heavy-mineral-concentrate samples, Valdez 1°×3° quadrangle, Alaska. All concentrations are in parts per million, except for Fe, Mg, Ca, and Ti, which are in percent. N, L, and G refer to samples in which concentrations could not be detected at the lower determination limit, were reported as observable but were less than the lower determination limit, and were reported as observable but were greater than the upper determination limit, respectively.

Table 3. Geochemical thresholds for selected elements for various sample media.
[All elements in parts per million except Fe, which is in percent]

Element	Stream-sediment samples		Nonmagnetic heavy-mineral-concentrate samples	
	Threshold value	Lower percentile of anomalous value	Threshold value	Lower percentile of anomalous value
Fe	20	99	20	82
Mn	3,000	98	3,000	88
Ag	0.5L	99	1	88
As	200L	99	500L	95
Au	--	--	20L	95
B	300	95	500	95
Ba	3,000	99	2,000	98
Be	1.5	97	3	99
Bi	--	--	50	95
Co	100	91	100	91
Cr	700	96	1,000	94
Cu	200	88	500	80
Mo	5L	99	10L	94
Ni	200	97	300	94
Pb	70	95	300	92
V	700	93	700	99
W	--	--	100L	96
Zn	200	98	500L	95
AA-Au	0.05	89	0.45	87
AA-Cu	110	95	--	--
AA-Zn	170	96	240	94

economic significance, gold and silver, although highly censored, were included in the heavy-mineral-concentrate factor analysis. Factor analysis calculations, both with and without these two elements, resulted in little difference in factor loadings for other elements. For all elements used in the factor analysis, the censored data were treated as follows:

1. All values of an element qualified with an N were changed to 0.5 of the lower limit of detection for that element.

2. All values of an element qualified with an L were changed to 0.7 of the lower limit of detection for that element.

3. All values of an element qualified with a G were changed to 1.3 times the maximum detected value.

In factor analysis, similarly behaving experimental variables (elements) are placed into groups termed factors. Specific rock types or ore deposit types are commonly represented by distinct suites of trace elements, and therefore certain factors may indicate these common geochemical signatures in the study area. Factor loadings for the sediment and concentrate data sets are listed in tables 4 and 5, respectively. The factor loadings, which depict the influence of each variable on a factor, may be interpreted similarly to correlation coefficients. The optimal number of factors chosen from each data matrix, and discussed following, was based on the breaks in slope on plots of factor number versus total variance. Factor scores measure the effect a particular factor has on each sample site. A high score for a given sample signifies that the element association represented by that factor is strong.

FACTOR-ANALYSIS ASSOCIATIONS

A three-factor model that explains 70 percent of the total variance (table 4) was selected as most appropriate for summarizing broad geochemical trends in the AMRAP stream-sediment data. Samples having the highest scores onto factor 1 (Fe-Co-Mg-V-Sc-Cu-Cr-Ni-Ca) delineate four areas underlain by mafic and ultramafic rocks in the Valdez quadrangle (fig. 6). The largest of these areas is in the northwest part of the study area along both sides of the Border Ranges fault system. Anomalous samples collected within the Peninsular terrane north of the fault system are derived from the Border Ranges ultramafic-mafic

Table 4. Factor loadings for the first three factors after R-mode factor analysis with Varimax rotation of the log-transformed stream-sediment data base.

Total variance explained by three factors equals 70 percent. Leaders (--) indicate that loadings less than |0.40| have been omitted

Element	1	2	3
Fe	0.92	--	--
Mg	0.89	--	--
Ca	0.75	--	--
Ti	0.61	--	--
Mn	--	--	--
B	--	0.58	0.51
Ba	--	0.91	--
Be	–0.56	0.59	--
Co	0.92	--	--
Cr	0.80	--	--
Cu	0.82	--	--
La	--	0.49	--
Ni	0.79	--	--
Pb	--	0.76	--
Sc	0.85	--	--
Sr	--	--	–0.79
V	0.89	--	--
Y	0.52	0.70	--
Zr	--	0.78	--
AA-Cu	0.49	--	0.71
AA-Zn	--	0.59	0.69
Percent total variance	39	21	10

assemblage and from andesitic and basaltic volcanic rocks and volcanogenic sedimentary rocks of the Talkeetna Formation. To the south, sediment source lithologies include melange containing serpentinized ultramafic rocks, amphibolite facies metamorphic rocks containing lenses of mafic and ultramafic rocks, and layered quartz gabbro (Winkler, Nokleberg, and others, 1981). The second area defined by samples with high scores onto factor 1 is southeast of the town of Tonsina. This area is also underlain by rocks of the Border Ranges ultramafic-mafic assemblage. Within the Wrangellia terrane, samples enriched in the mafic element suite cluster along Elliot Creek (to the north of the Chitina fault) and in the Canyon Creek–Summit Lake region (to the south of the Chitina River). The former area is underlain by tholeiitic basalt (Nikolai Greenstone), and the latter area is underlain by a variety of metasedimentary, mafic volcanic, serpentinized ultramafic, and intermediate to mafic metaplutonic rocks (Haley Creek terrane and Skolai Group of Winkler, Nokleberg, and others, 1981). Stream-sediment samples collected from the Prince William terrane and the southern part of the Valdez Group in the Chugach terrane consistently have lowest scores for factor 1. These samples consistently contain the lowest concentrations of mafic elements.

The factor 2 association (Ba-Zr-Pb-Y-Be-Zn-B-La) reflects stream sediments that have a significant geochemical component derived from felsic igneous rocks. Samples having the highest scores onto this factor are in the Chugach terrane between the Tiekel River and Klutina Lake (fig. 6). The geology of this area consists of both melange of the McHugh Complex and metasedimentary rocks of the Valdez Group. More significantly, the area contains an abundance of sills, dikes, and small stocks of felsic to intermediate composition (Winkler, Nokleberg, and others, 1981) that are relatively enriched in the factor 2 element suite. Samples having anomalously low scores onto factor 2 are widespread in the northwest corner of the study area and are spatially associated with mafic and ultramafic volcanic and intrusive rocks in the area. Stream-sediment samples from these units contain the lowest concentrations for many of the elements that have high loadings onto factor 2.

Sediment samples having high scores onto factor 3 ([–Sr]-Cu-Zn) cluster in three parts of the Chugach terrane (fig. 6); those having lowest scores are predominantly in the northeast corner of the Valdez quadrangle. Anomalous samples are in a cluster in the northwest part of the study area within melange between the Border Ranges fault zone and Iceberg fault. This area contains abundant mafic rocks. The anomalous concentrations of zinc and copper in stream sediments, coupled with very low concentrations of strontium, most likely reflect local lithology. In addition, areas having anomalously high scores onto factor 3 broadly define two locations that have high favorability for base-metal-bearing mineral occurrences within rocks of the Valdez Group. These include the Port Valdez gold district and the area from Greyling Lake north to Bence Mountain in the center of the quadrangle. No metallic mineral occurrences are recognized in the latter area, and the data suggest a new tract that is geochemically favorable for the presence of such occurrences. Stream-sediment samples in the northeast corner of the study area have the most negative scores onto factor 3 and are spatially associated with rocks of the Chitina Valley batholith and, to a lesser extent, with the Haley Creek metamorphic assemblage and the calc-alkaline volcanic flows in the Wrangell Mountains. The low concentrations of zinc and copper determined by atomic absorption analysis of partial leaches indicate relatively low amounts of these elements in non-silicate-bound mineral phases in the intrusive rocks and perhaps the andesite flows. Anomalously high strontium concentrations for samples having the lowest scores onto factor 3 predominantly reflect

Table 5. Factor loadings for the first six factors after R-mode analysis with Varimax rotation of the log-transformed nonmagnetic heavy-mineral-concentrate data base.
[Total variance explained by six factors equals 74 percent. Leaders (--) indicate that loadings less than |0.40| have been omitted]

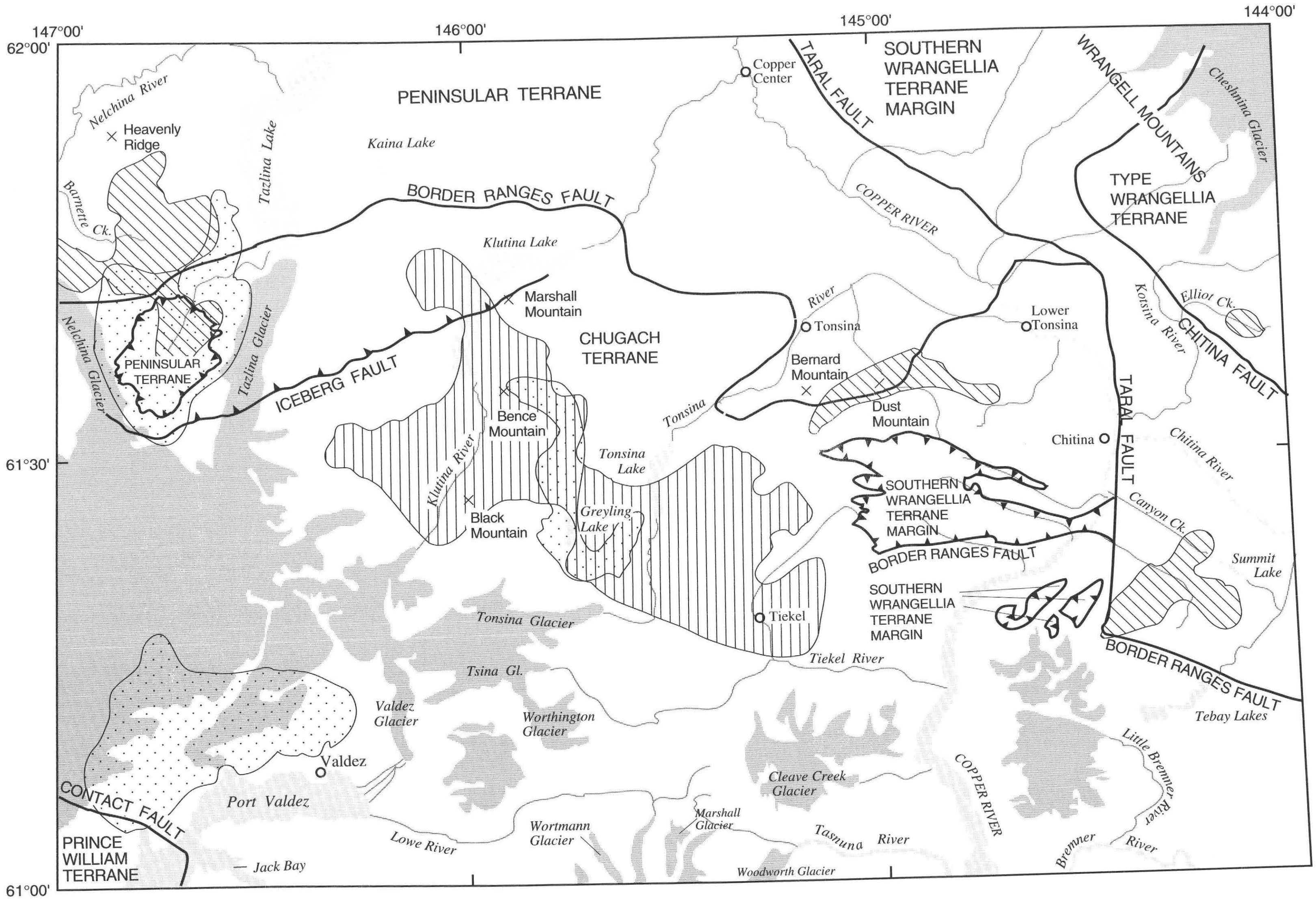
Element	1	2	3	4	5	6
Fe	--	0.75	--	--	--	--
Mg	–0.50	--	--	--	–0.42	--
Ca	--	--	0.74	--	--	--
Ti	0.84	--	--	--	--	--
Mn	--	--	--	0.71	--	--
Ag	--	--	--	--	0.70	--
B	0.58	--	--	–0.52	--	--
Ba	0.84	--	--	--	--	--
Be	0.69	--	--	--	--	--
Co	--	0.86	--	--	--	--
Cr	--	--	--	--	--	0.80
Cu	0.42	0.44	--	--	0.55	--
La	0.71	--	--	--	0.44	--
Ni	--	0.77	--	--	--	--
Pb	0.62	--	--	--	0.60	--
Sc	--	--	0.64	--	--	0.40
Sr	0.44	-0.52	--	--	--	--
V	--	--	0.80	--	--	--
Y	0.83	--	--	--	--	--
Zr	0.80	--	--	--	--	--
AA-Au	--	--	--	--	0.76	--
AA-Zn	0.64	--	--	--	--	–0.44
Percent total variance	32	14	12	6	5	5

contributions from the intrusive bodies. Miller and others (1982) reported that samples of granodiorite and diorite from the area having the low factor scores contain 1,500–2,000 ppm Sr, the highest background values for any rock type in the Valdez quadrangle.

Six factors explain 74 percent of the variance within the heavy-mineral-concentrate data (table 5). The first factor (Ti-Ba-Y-Zr-La-Be) probably reflects concentrate samples that contain a high proportion of accessory minerals such as zircon, sphene, barite, and rutile. Samples having highest scores are generally scattered throughout areas underlain by turbidite units of the Valdez Group. A few distinct clusters of samples having high scores are between Wortmann and Woodworth Glaciers on the southern edge of the Valdez quadrangle, east of the Bremner River in its southeastern corner, and between the Copper River and Tiekel near its center (fig. 7). Almost all samples having anomalous negative scores are in the northwest corner of the quadrangle. They delineate mafic and ultramafic rocks in the vicinity of the Border Ranges fault zone that are relatively depleted in many of the elements that have high loadings onto factor 1.

Many of the heavy-mineral-concentrate samples with the highest proportions of pyrite are interpreted to be defined by some of the highest scores onto factor 2 (Co-Ni-Fe-[–Sr]). These samples are mainly from an area on the south side of the lower part of the Tiekel River just west of the Copper River, from an area east of the Little Bremner River, and from the area east of Bence and Black Mountains in the center of the quadrangle (fig. 7). Less extensive clusters of anomalous samples are within the Port Valdez mining district and between Woodworth and Marshall Glaciers. Many anomalous samples in the northeast corner of the study area are indicative of relatively high iron, cobalt, and nickel values in samples derived from flows of the Wrangell Lava. A cluster of samples in the headwaters of O'Brien Creek, Haley Creek, and Uranatina River that have anomalously low scores represent heavy-mineral-

Figure 6 (facing page). Areas containing clusters of samples characterized by high positive scores onto the first three significant factors from factor analysis of the stream-sediment data, Valdez 1°×3° quadrangle, Alaska.



EXPLANATION

Area of samples having anomalously high factor scores for stream-sediment samples

Factor 1 (Fe-Co-Mg-V-Sc-Cu-Cr-Ni-Ca)

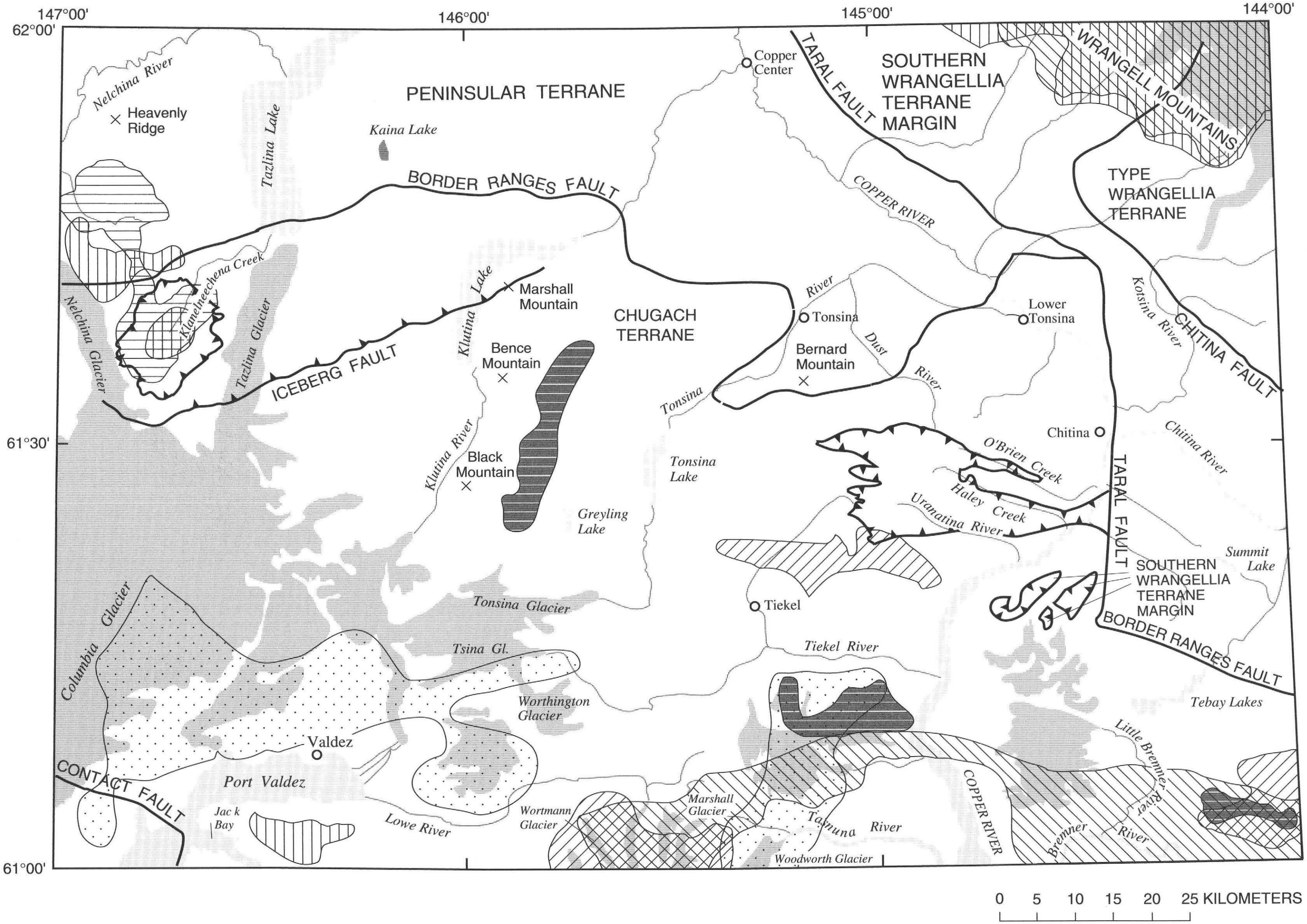
Factor 2 (Ba-Zr-Pb-Y-Be-Zn-B-La)

Factor 3 ([–Sr]-[AA]-Cu-Zn)

Glacier or icefield

Fault—Approximately located

Thrust fault—Approximately located. Saw teeth on upper plate



EXPLANATION

Area of samples having anomalously high factor scores for stream-sediment samples

- **Factor 1 (Ti-Ba-Y-Zr-La-Be)**
- **Factor 2 (Co-Ni-Fe-[–Sr])**
- **Factor 3 (V-Ca-Sc)**
- **Factor 4 (Mn-[–B])**
- **Factor 5 (Au-Ag-Pb-Cu)**
- **Factor 6 (Cr-[–Zn]-Sc)**
- **Glacier or icefield**
- **Fault**—Approximately located
- **Thrust fault**—Approximately located. Saw teeth on upper plate

concentrate samples containing consistently low concentrations of iron, nickel, and cobalt and high concentrations of strontium. These anomalies likely reflect lithogeochemistry of the underlying metamorphosed plutonic and sedimentary rocks.

Concentrate samples having high scores onto factor 3 (V-Ca-Sc) correlate with an area near the western edge of the study area where serpentinized mafic and ultramafic rocks crop out on both sides of the Border Ranges fault zone (fig. 7). In the Port Valdez district and in the Bence Mountain–Black Mountain area, clusters of samples having low scores onto this factor outline areas of Valdez Group rocks that have relatively low vanadium, calcium, and scandium concentrations despite high values for other mafic elements including copper and zinc. These samples most likely are enriched in sulfide mineral grains rather than fragments of mafic volcanic rock.

Much of the southeast edge of the study area is defined by concentrate samples having highest scores onto factor 4 (Mn-[–B]). Samples from this area (fig. 7), which is underlain by rocks of the Valdez Group, contain the highest manganese values from the geochemical survey. The source of the manganese is uncertain, but it reflects a northward continuation of a trend of anomalous manganese described to the south of the Valdez quadrangle in the Gravina River watershed (Goldfarb and others, 1989). A second group of concentrate samples having anomalously high scores onto factor 4 is in the northeast corner of the study area in the Wrangell Mountains. Volcanic flow rocks from the range are distinguished by samples containing extremely low amounts of boron and somewhat elevated amounts of manganese. Just to the south of this area, boron-rich concentrate samples that have anomalously low scores onto factor 4 are spatially associated with the western edge of the Kotsina mining district (fig. 3). The reason for the correlation is uncertain; perhaps the boron is derived from the dikes and small stocks that are scattered throughout the district. Additional samples having relatively low scores onto factor 4 are between Nelchina and Tazlina Glaciers and correlate with outcrops of melange south of the Border Ranges fault zone.

Concentrate samples enriched in elements that have high loadings onto factor 5 (Au-Ag-Pb-Cu) define the broadest zones of precious-metal favorability within the study area (fig. 7). The majority of samples having high scores onto factor 5 define the extent of gold-bearing veins in the Port Valdez district. Anomalous samples extend from the southwest corner of the Valdez quadrangle for about 60 km to the east. A second cluster of anomalous samples extends from the Tiekel River south to the Valdez quadrangle boundary. Samples having the most negative factor 5 scores, indicating low concentrations of all highly loaded elements, mostly correlate with outcrops of melange of the McHugh Complex.

Concentrate samples having the highest scores onto factor 6 (Cr-[–Zn]-Sc) indicate mafic and ultramafic source rocks that contain high concentrations of chromium and relatively low amounts of non-silicate-bound zinc. Areas delineated by samples having highest scores include part of the Wrangell Mountains, an area south of Port Valdez, and the headwaters of Klanelneechena Creek and an area northeast of Nelchina Glacier, both in the northwest part of the study area (fig. 7).

Figure 7 (facing page). Areas containing clusters of samples characterized by high positive scores onto the first six significant factors from factor analysis of the heavy-mineral-concentrate data, Valdez 1°×3° quadrangle, Alaska.

SPATIAL ANALYSIS OF GEOCHEMICALLY ANOMALOUS AREAS

Maps from the AMRAP survey showing individual element concentrations and factor score values were used to delineate many of the 31 geochemically anomalous areas in the Valdez quadrangle (table 6, figs. 8–38, plate 1). A few of the areas were defined mostly by data from the Chugach National Forest survey (areas 2, 4–6, and 8) and the NURE survey (areas 10, 14, 24, and 31). Geochemical methods and statistical analysis of data from the Chugach survey are given in Goldfarb and Smith (1987). Anomalous element values for samples from the 98 Chugach survey sample sites were identified primarily by using threshold values from the Valdez AMRAP survey (table 3). A summary of the NURE survey is given in the following section of this report. Following that summary, detailed descriptions of geochemical anomalies from all 31 areas are presented. These descriptions and the element summaries presented in table 6 include only the more significant anomalies; data shown in figures 8–38 represent a much more comprehensive summary of anomalous element values. Most of the 31 areas are geochemically favorable for the presence of metallic mineral resources.

NURE GEOCHEMICAL SURVEY

GEOCHEMICAL METHOD

Analytical results from the hydrogeochemical and stream sediment reconnaissance part of the U.S. Department of Energy's NURE program (Sharp and Hill, 1978; D'Andrea and others, 1981) were statistically evaluated as part of the present study. Samples collected during the

Table 6. Summary of geochemically anomalous areas, Valdez 1°×3° quadrangle, Alaska.
[Areas shown by number on plate 1. Parentheses indicate that element(s) is less consistently anomalous]

Area	AMRAP stream-sediment samples	AMRAP heavy-mineral-concentrate samples	NURE stream-sediment samples	Other samples
1. Prince William terrane		(Au, Ag, Cu, Fe)	Ba, (Co, Mn)	(As),[1] (Au, Zn)[2]
2. Twin Falls Creek	Zn	(B)	Cu, Sn, (Pb, U)	Cu,[2] (As, B, Bi, Pb, W)[2]
3. Port Valdez mining district	(Au)	Ag, Au, Cu, (As, Co, Fe, Mo, Ni, Pb, Zn)	(Au)	
4. South Port Valdez			(Th, U)	As[1], Pb,[1] As[2], Pb,[2] (Ag, Bi)[2]
5. Central sulfide belt	(Au)	(Cu, Fe, Pb)	(Cu)	Ag,[2] As,[2] Co,[2] Cu,[2] Fe,[2] Ni,[2] Pb,[2] (Au, Bi, Mn, Sb, W),[2] Cu,[3] (Zn)[3]
6. Woodworth Glacier	(Au)	(Au, Cu, Fe, Pb)	(Th)	Ag,[2] As,[2] Au,[2] B,[2] Bi,[2] Cu,[2] Pb,[2] W,[2] (Fe, Be, Co, Ni, Sn, Zn)[2]
7. Cascade Creek		Au, (Ba, Zn)		
8. Cleave Creek Glacier	(Au, Mn)	(Ag, As, Au, Cu, Fe, Mn, Zn)	(Th, U)	
9. East side of the Copper River	(Au)	Au, (Ag, Cu, Mn)	(Au)	
10. Bremner River			U, (Th)	
11. East Fork of the Bremner River	(Au)	Ag, Cu, Fe, Mn, (Pb, Zn)		
12. East of Tebay Lakes		Au		
13. Tonsina mining district	Au,(Pb)	Au, (Ag, Cu)	(Au)	
14. Tiekel River–Stuart Creek	(Pb)		U, (Pb)	
15. Ernestine Creek	Au	(Ag, Cu)		
16. Mt. Ourand	(Pb, Zn)	Ag, Fe, Cr, Cu, Mo, Pb		
17. North of Tonsina Glacier		Au		
18. Black Mountain	(Cu, Pb, Zn)	Fe, Co, Mo, W, Zn, (Ag, Au, Be, Mn, Ni, Pb)	(Zn)	
19. Greyling Lake	Be, Pb, Zn		U, (Pb)	
20. Kimball Pass	Au		Zn, pH,[7] (Ba, Cu, U)	
21. Bernard and Dust Creeks	Cr, Fe, Mg, Ni, V		Cr, (Ni)	Cr,[4] Cr[5]
22. Summit Lake	Co, Cu, Ni, Fe, (Pb, Cr, Zn)		(U)	(Cu, Ni, Pb, Zn)[6]
23. Taral Creek	Co, Cu	Ag, Cu	(Mn)	
24. Hallet River–Iceberg Lake			Sb, Mn, Zn, (Ag, Mg, Co, Ni, Cu, Ti)	
25. Klanelneechena Creek	B, Fe, Co, Cu, Cr, V, Mg, (Ni)	Mg, (Ag, B, Cr)	Fe, Co, Cr, Mn, V, (Cu, Ni)	
26. Nelchina Glacier	Cr, Fe, Co, Cu, Ni, V, Mg, Ca, (B)	Cr, Mg, Ca	Co, Cu, Ni, (Cr, Mn)	
27. High Lake	(Co, V)	Mo		
28. Kotsina River mining district	B, Cu, Mo, V, (Fe)	Cu, (B, Ba, Mo)	Sb	U[7]
29. Wrangell Mountains		Fe, Mg, Co, Ni, (Mn)		
30. Dadina River		Zn		
31. Copper River				U[8]

[1]Stream sediment, Chugach survey (Goldfarb and others, 1984).
[2]Heavy-mineral concentrate, Chugach survey (Goldfarb and others, 1984).
[3]Stream sediment (Rose, 1965).
[4]Stream sediment (Sutley and others, 1990).
[5]Heavy mineral-concentrate (Sutley and others, 1990).
[6]Stream sediment (Herreid, 1970).
[7]Stream water, NURE (Sharp and Hill, 1978; D'Andrea and others, 1981).
[8]Lake water, NURE (Sharp and Hill, 1978; D'Andrea and others, 1981).

Table 7. Statistical summary for 457 –100-mesh stream-sediment samples from the NURE survey, Valdez 1°×3° quadrangle, Alaska.

[All values in are parts per million except values for Al, Ca, Fe, K, Mg, and Na, which are in percent. Uranium was determined by delayed neutron counting; Ag, Bi, Cd, Cu, Nb, Ni, Pb, Sn, and W by X-ray fluorescence; Be and Li by emission spectrography; and all other elements by neutron activation analysis. B indicates number of samples with no data reported; L indicates number of samples qualified with a less than. LDL is lower determination limit as listed in Los Alamos National Laboratory (table I, 1983); limits are not given therein for Cl, Rb, and Sm. For elements determined by neutron activation analysis, the lower determination limit is a complex function of the total composition and mass of each individual sample. The limits listed by Los Alamos are average values for Alaska calculated on the basis of typical 4-g samples. In many cases in this table, therefore, the average estimate for an element's lower determination limit exceeds minimum values from the Valdez quadrangle data set]

Element	B	L	LDL	Minimum value	Median value	Percentile 90th	Percentile 95th	Percentile 97.5th	Maximum value
U	0	0	0.01	0.09	2.3	3.6	4.1	5.4	21.5
Ag	18	438	5	5L	5L	5L	5L	5L	5
Bi	18	405	5	5L	5L	5L	6	6	10
Cd	18	412	5	5L	5L	5L	5L	5L	8
Cu	18	0	10	12	48	84	102	119	350
Nb	18	431	20	20L	20L	20L	20	20	30
Ni	18	32	15	15L	34	60	70	81	137
Pb	18	310	5	5L	5L	10	12	16	69
Sn	18	434	10	10L	10L	10L	10L	13	32
W	18	427	15	15L	15L	15L	15	15	29
Be	42	9	1	1.0L	2.0	3.0	3.0	3.0	5
Li	42	0	1	1.0	27	49	65	73	136
Al	0	0	0.32	1.7	6.6	7.8	8.1	8.4	9.2
Au	0	434	0.05	0.04L	0.1L	0.17L	0.24	0.45	3.29
Ba	0	49	150	162L	556	892	978	1,037	1,285
Ca	0	3	0.1	0.2L	2.3	4.6	6.2	6.8	8.0
Ce	0	15	10	6L	46	71	78	83	116
Cl	0	401	---	81L	138L	211	314	376	1,946
Co	0	7	1.7	0.1L	16.6	30.4	37.3	45.0	271.0
Cr	0	5	10	24L	104	166	222	304	1,074
Cs	0	306	2	1.3L	2.6L	4.9	6.2	8.0	18.6
Dy	0	9	0.7	1L	4	5	6	6	8
Eu	0	8	0.4	0.5L	1.4	1.7	1.8	2.0	5.1
Fe	0	0	0.11	1.2	4.1	6.4	7.5	8.5	33
Hf	0	34	1.3	1.4L	5.0	9.3	12.1	14.6	20.3
K	0	67	0.34	0.3L	1.1	1.6	1.7	1.9	2.7
La	0	66	7	4L	23	34	39	42	80
Lu	0	44	0.1	0.1L	0.3	0.4	0.5	0.5	0.7
Mg	0	7	0.27	0.3L	1.2	2.1	2.6	3.2	3.7
Mn	0	0	55	197	822	1,387	1,574	1,722	6,186
Na	0	0	0.1	0.5	1.9	2.4	2.5	2.7	3.0
Rb	0	413	---	28L	49L	74L	86	101	285
Sb	0	446	1	1L	3L	5L	6L	6L	15
Sc	0	0	0.9	4.7	17.4	28.3	34.9	48.1	98.2
Sm	0	19	---	0.6L	4.1	6.1	6.5	7.1	10.9
Sr	4	400	400	247L	369L	513	592	674	880
Ta	0	455	1	1L	1L	3L	4L	4L	9
Tb	0	430	1	1L	1L	2L	3	3	5
Th	0	42	1	1.0L	4.8	7.9	9.1	10.5	16.4
Ti	0	6	750	1,073L	4,652	6,521	7,227	8,021	12,000
V	0	0	6	34	132	210	249	304	554
Yb	0	153	1	1.2L	3.0	4.2	4.8	5.4	11.9
Zn	9	264	100	12L	79L	152	184	220	443

NURE survey included 457 –100-mesh stream sediments, 43 –80-mesh stream sediments, 14 –100-mesh spring sediments, 500 –100-mesh lake sediments, 18 spring waters, 520 stream waters, and 685 lake waters. Each water sample was unfiltered and acidified to a pH of less than 1.0 with 8N reagent grade HNO_3. The pH of the water was measured with a calibrated, portable pH meter and recorded in the field to the nearest tenth of a pH unit. Each

Table 8. Statistical summary for 500 –100-mesh lake-sediment samples from the NURE survey, Valdez 1°×3° quadrangle, Alaska.
[All values in are parts per million except for Al, Ca, Fe, K, Mg, and Na, which are in percent. Uranium was determined by delayed neutron counting; Ag, Bi, Cd, Cu, Nb, Ni, Pb, Sn, and W by X-ray fluorescence; Be and Li by emission spectrography; and all other elements by neutron activation analysis. B indicates number of samples with no data reported; L indicates number of samples qualified with a less than. Lower determination limits for all elements are the same as those in table 7. For elements determined by neutron activation analysis, the lower determination limit is a complex function of the total composition and mass of each individual sample. The limits listed by Los Alamos are average values for Alaska calculated on the basis of typical 4-g samples. In many cases, therefore, the average estimate for an element's lower determination limit exceeds minimum values from the Valdez quadrangle data set listed in this table]

Element	B	L	Minimum value	Median value	Percentile			Maximum value
					90th	95th	97.5th	
U	0	0	0.22	1.7	2.8	3.4	4.4	17.3
Ag	51	448	5L	5L	5L	5L	5L	4
Bi	51	419	5L	5L	5L	5	5	10
Cd	51	434	5L	5L	5L	5L	5	7
Cu	51	0	13	48	74	91	102	318
Nb	51	436	20L	20L	20L	20L	20	41
Ni	51	40	15L	29	47	54	65	111
Pb	51	399	5L	5L	5	8	10	108
Sn	51	446	10L	10L	10L	10L	10L	15
W	51	446	15L	15L	15L	15L	15L	22
Be	90	43	1L	2	2	3	3	4
Li	89	0	1	12	35	45	58	108
Al	0	0	0.9	6.1	7.6	7.9	8.2	9.7
As	462	5	5L	10	20	24	24	65
Au	0	499	0.05L	0.13L	0.18L	0.23L	0.26L	0.17
Ba	0	115	183L	477	707	832	934	1,381
Ca	0	10	0.2L	2.7	3.8	4.3	5.2	33.3
Ce	0	77	6L	33	50	55	60	73
Cl	0	333	102L	166L	357	519	766	2,992
Co	1	58	0.1L	13.1	21.6	27	31.2	46.7
Cr	0	48	13L	81	126	100	183	298
Cs	0	434	1.2L	3.0L	3.3	4.9	6.5	9.9
Dy	0	56	1L	4	5	5	6	7
Eu	0	73	0.4L	1.1	1.5	1.7	1.9	2.3
Fe	0	2	0.01L	3.2	4.8	5.7	6.5	8.3
Hf	0	167	1.4L	3.5	5.1	5.6	5.9	7.8
K	0	184	0.3L	0.8	1.3	1.4	1.6	2.4
La	0	261	6L	33L	23	26	29	35
Lu	0	217	0.1L	0.2	0.3	0.4	0.4	0.6
Mg	0	27	0.2L	1.1	1.6	1.9	2.3	3.7
Mn	0	0	65	574	890	1,094	1,292	4,485
Na	0	0	0.2	1.7	2.2	2.3	2.4	2.7
Rb	0	495	29L	64L	98L	117L	158L	121
Sb	0	497	1L	3L	5L	6L	7L	10
Sc	0	0	2.2	15.1	21.8	25	27.9	47.5
Sm	0	64	0.8L	3.1	4.6	5.2	5.5	7.3
Sr	5	454	250L	407L	689L	471	591	1,355
Tb	0	488	1L	1L	2L	3L	11L	2
Th	0	122	1L	3.4	5.3	6.1	6.8	10.6
Ti	0	41	710L	4133	5,679	6,266	6,831	10,130
V	0	2	11L	117	164	189	217	299
Yb	0	379	1.7L	3.4L	3.1	3.7	4	5.3
Zn	4	329	11L	105L	171	196	221	334
Zr	462	0	45	99	146	148	148	175

25-g stream- and spring-sediment sample was composited from three adjacent locations. Lake-sediment samples were taken from as near the center of each lake as possible by dropping a tethered stainless steel bottom-sample device from a helicopter.

Most sediment samples (–100-mesh) were analyzed by delayed neutron counting for U, by energy dispersive X-ray fluorescence for Ag, Bi, Cd, Cu, Nb, Ni, Pb, Sn, and W, by arc-source emission spectrography for Be and Li, and by instrumental neutron activation analysis for Al, Au, Ba, Ca,

Table 9. Statistical summary for pH values and uranium contents of 685 lake-water, 520 stream-water, and 18 spring-water samples from the NURE survey, Valdez 1°×3° quadrangle, Alaska.

	pH						
	Minimum value	5th percentile	10th percentile	Median value	90th percentile	95th percentile	Maximum value
Lake	4.0	7.2	7.3	8.0	8.6	8.8	10.0
Stream	3.6	5.9	6.2	7.2	8.2	8.4	10.0
Spring	4.5	5.0	5.5	7.3	7.7	8.1	8.2

	Uranium content (in parts per billion)					
	Minimum value	Median value	90th percentile	95th percentile	97.5th percentile	Maximum value
Lake	0.01	0.16	0.56	0.88	1.15	9.73
Stream	0.01	0.21	0.69	1.10	1.35	18.30
Spring	0.01	0.22	0.50	0.54	0.54	0.55

Ce, Cl, Co, Cr, Cs, Dy, Eu, Fe, Hf, K, La, Lu, Mg, Na, Rb, Sb, Sc, Sm, Sr, Ta, Tb, Th, Ti, V, Yb, and Zn. Water samples and –80-mesh sediment samples were only analyzed for U by delayed neutron counting.

STATISTICAL METHOD AND GEOCHEMICAL ANOMALIES

Data in table 7 for –100-mesh stream-sediment samples, table 8 for –100-mesh lake-sediment samples, and table 9 for water samples summarize most of the results from the NURE survey. Geochemical thresholds for the stream-sediment and stream-water data (table 10) were selected using methods similar to those used for determining threshold values for the AMRAP data.

Although the NURE –100-mesh stream-sediment and stream-water survey covered the entire Valdez quadrangle, it provides much less information than does the AMRAP survey. Interpretation of the NURE sediment and water data alone would have led to identification of very few of the anomalous areas delineated from the AMRAP survey. This is due, in part, to the lack of collection of heavy-mineral-concentrate samples during the NURE survey. Collection of such a sample medium, representing a large volume of stream-sediment material, is critical when trying to detect a few metallic grains along a stretch of stream channel. In addition, NURE sample sites were commonly placed along high-order streams and rivers rather than along first- and second-order channels. Sample density was erratic; many sites were clustered along the Richardson Highway and other areas of easy access, whereas the more remote parts of the Valdez quadrangle were unsampled. Finally, the high lower determination limits for some elements, such as silver, and the lack of analyses for other elements, such as arsenic, hinder the usefulness of the stream-sediment data for precious-metal exploration.

Gold was detected in 23 of the 457 NURE stream-sediment samples, from generally scattered localities across the quadrangle. Three samples containing detected gold cluster along Mineral Creek (in area 3) and three others along the eastern side of area 9. The remaining gold anomalies are at isolated locations, some within other geochemically anomalous areas identified using the AMRAP survey results. The NURE gold values are, however, for the most part ineffective in defining broad tracts of land favorable for the presence of precious-metal mineral occurrences. The sample having the highest gold concentration, 3.29 ppm, appears to have been collected within the main channel of the Tsina River to the north of Mount

Table 10. Geochemical thresholds for selected parameters in the NURE stream-sediment and stream-water data, Valdez 1°×3° quadrangle, Alaska.
[In parts per million unless otherwise indicated]

Element	Threshold value	Lower percentile of anomalous values
	Stream sediments	
Ag	5	>99
Au	0.10	95
Ba	1,035	97
Bi	5	92
Cd	5	94
Co	33	93
Cr	189	92
Cu	85	91
Fe (percent)	7.2	94
Mn	1,800	98
Ni	63	91
Pb	13	96
Sb	3	98
Sn	13	99
Th	9.4	96
W	15	97
U	4.0	94
V	260	95
Zn	197	97
	Stream waters	
pH	<6.0	94
U (parts per billion)	0.98	94

Dimond (plate 1) and may have been eroded from anywhere within a region of greater than 100 km^2.

NURE sediment samples containing anomalous concentrations of antimony are within and to the northeast of the boundaries of the Kotsina River area (area 28) and help define a new anomalous area to the west of Terrace Mountain (area 24). Pairs of samples enriched in lead group near Mount Tiekel, on the north side of the Lowe River (area 3), and east of Greyling Lake (area 19). Samples containing anomalous amounts of copper are in and near area 26, on the west side of Valdez Arm (area 2), and scattered along the Lowe and Tasnuna Rivers. The most zinc-rich NURE sediment samples cluster within and to the north of area 20, define part of area 24, and are within and near area 18. The areas between Liberty Creek and the Little Tonsina River (area 21) and between Nelchina and Tazlina Glaciers (areas 25 and 26) include almost all NURE sediment samples containing anomalous amounts of chromium. Similar to samples from the AMRAP survey, the NURE sediments containing the anomalous chromium are derived from chromite-bearing rocks of the Border Ranges ultramafic-mafic assemblage. Cobalt and nickel are also consistently anomalous in samples from the Nelchina-Tazlina Glacier areas.

NURE stream sediments containing anomalous amounts of uranium cluster in three areas underlain by rocks of the Valdez Group. These include an area south of the Bremner River (area 10), an area north of the Contact fault in the vicinity of Valdez Arm (areas 2 and 4), and a large area from the mouth of Dewey Creek northwest to Greyling Lake (area 14). In the latter area, a few of the highest values for uranium in stream waters are at two of the sediment sites. Anomalous thorium values in sediment samples are associated with uranium anomalies in the Bremner River and Valdez Arm areas. NURE stream-water samples having the lowest pH values form a distinct cluster within and downstream from area 20b. These acidic pH values suggest extensive dissolution of sulfide mineral prospects in the Kimball Pass area.

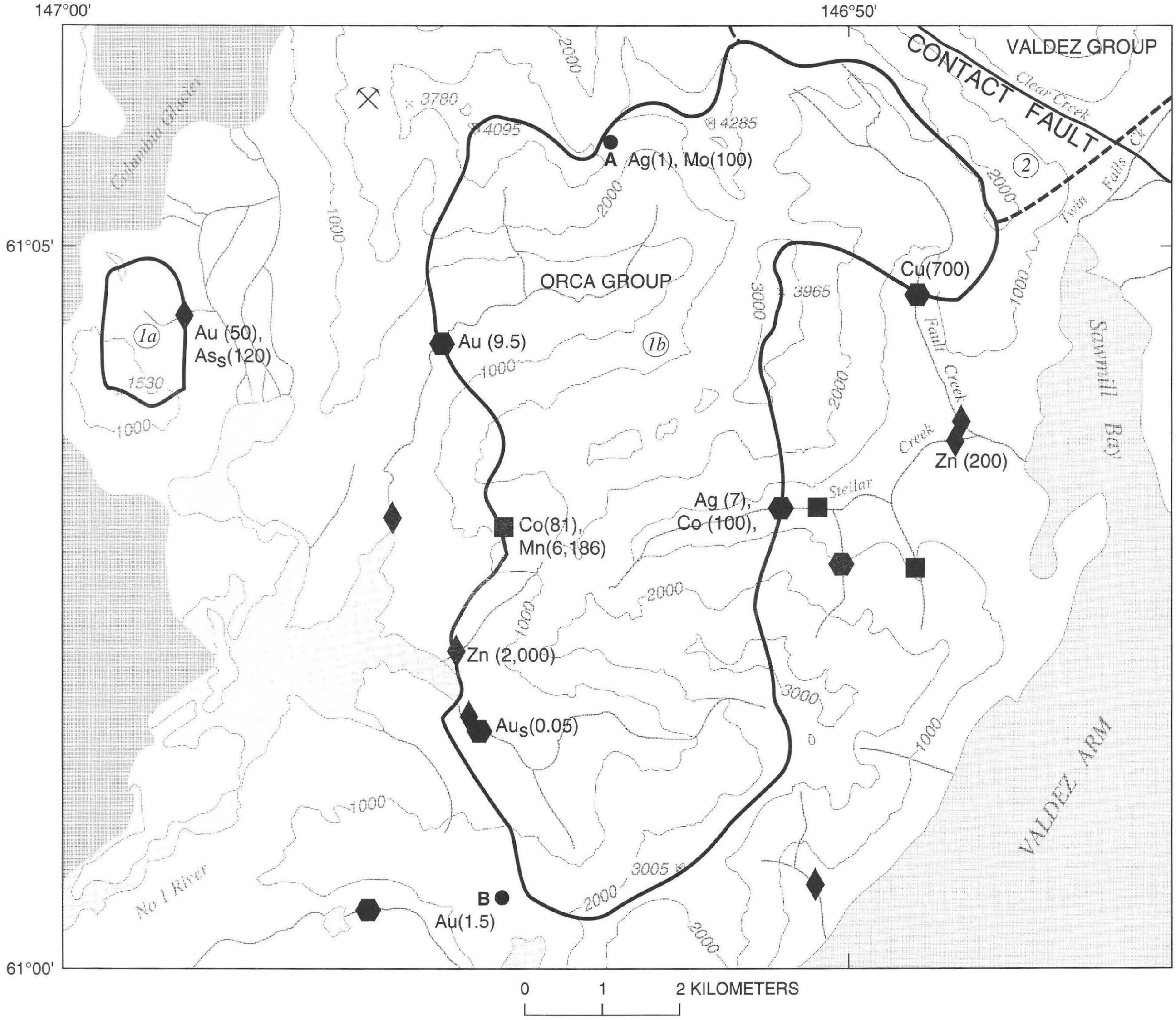
The spring-sediment, spring-water, and –80-mesh stream-sediment samples from the NURE survey are too few and scattered to provide any helpful information. Uranium concentrations in lake waters, however, clearly define one additional area of interest in the northeast part of the Valdez quadrangle (area 31). The –100-mesh lake-sediment data from the NURE survey were evaluated and generally are difficult to interpret. A major problem is that the majority of the lake-sediment samples were collected from areas of little relief in undifferentiated Quaternary deposits of the Copper River Lowlands. Therefore, much of the lake-sediment data likely do not reflect underlying, deeply buried lithologies. Very few lake-sediment samples were collected from the southern half of the Valdez quadrangle.

There is a broad spatial correlation between lake sediments that have elevated values for many of the mafic elements and rocks of the Border Ranges ultramafic-mafic assemblage. One distinct trend is evident in the lake-sediment uranium data; anomalous uranium concentrations in lake-sediment samples generally correlate with the uranium-rich stream-sediment samples that define area 14. Lake-sediment samples enriched in base- and precious-metals show no distinct patterns indicative of broad areas that are geochemically favorable for the presence of metallic mineral resources. A few of the isolated, highest values for some metals are discussed following in the descriptions of the geochemically anomalous areas. These include the lake-sediment sample that contains detected gold (area 8), the sample near area 30 that contains detected silver, and a sample containing 318 ppm Cu from near area 23. A lake-sediment sample from the southeast side of hill 4525 in R. 1 W., T. 3 S., in an area underlain by rocks of the McHugh Complex, contains 108 ppm Pb and also may be significant.

DESCRIPTION OF GEOCHEMICALLY ANOMALOUS AREAS

AREA 1—PRINCE WILLIAM TERRANE

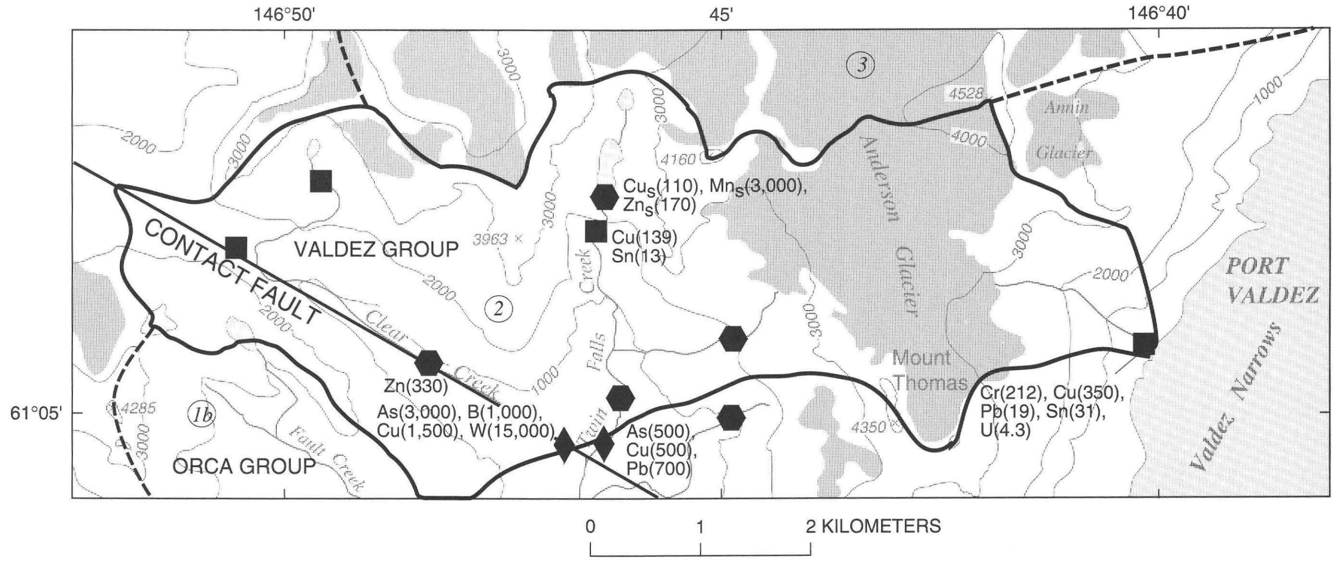
Two small anomalous areas (areas 1a, 1b) in the southwest corner of the Valdez quadrangle are underlain by sedimentary rocks of the Orca Group (fig. 8, pl. 1). No mineral occurrences are known from these areas, but a small gold-bearing quartz vein is northwest of area 1b on hill 3780 (Jansons and others, 1984). The larger of the two areas (area 1b) is delineated on the basis of four sites: one stream-sediment sample containing 0.05 ppm Au and three concentrate samples containing anomalous silver, gold, cobalt, or copper. The three concentrate samples also are characterized by anomalous scores onto factor 5 (described earlier). A concentrate sample in the area collected during the Chugach National Forest study (Goldfarb and others, 1984) contains 2,000 ppm Zn. A NURE stream-sediment sample collected along the western edge of area 1b, west of the Stellar Creek drainage divide, contains 6,186 ppm Mn and 81 ppm Co. A quartz-vein sample from the northwest corner of the area contains 1 ppm Ag and 100 ppm Mo, and a sample of sandstone from the ridge along the southern edge of the area contains 1.5 ppm Au (Miller and others, 1982). The smaller area (area 1a), to the west of the No 1 River, consists of a small drainage basin that yielded a sediment sample containing 120 ppm As and a concentrate sample anomalous in gold, both collected during the Chugach survey. Most of these anomalies in Orca Group rocks likely reflect the presence of gold-bearing quartz veins south of the Contact fault system.



EXPLANATION

- **Alaska Mineral Resource Assessment Program sample**—Values are in parts per million. Values are for concentrate samples except that accompanied by subscript "s," which is for a sediment sample
- **Chugach National Forest Survey sample**—Values are in parts per million. Values are for concentrate samples except that accompanied by a subscript "s," which is for a sediment sample
- **National Uranium Resource Evaluation sediment sample**—Values are in parts per million
- **Alaska Mineral Resource Assessment Program rock sample**—Values are in parts per million. **A** denotes quartz vein sample; **B** denotes sandstone sample
- **Gold-bearing quartz veins**
- **Boundary of geochemically anomalous area**
- **Boundary of adjacent geochemically anomalous area**
- (1b) **Number of geochemically anomalous area**
- **Fault**—Approximately located
- **Glacier**

Figure 8. Geochemically anomalous stream-sediment, heavy-mineral-concentrate, and rock samples within areas underlain by rocks of the Orca Group (geochemically anomalous areas 1a and 1b) (Prince William terrane), Valdez 1°×3° quadrangle, Alaska. Rocks of the Valdez Group of the Chugach terrane are present northeast of the Contact fault. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.



EXPLANATION

- ⬢ **Alaska Mineral Resource Assessment Program sample**—Values are in parts per million. Values are for concentrate samples except those accompanied by subscript "s," which are for a sediment sample
- ◆ **Chugach National Forest Survey concentrate sample**—Values are in parts per million
- ■ **National Uranium Resource Evaluation sediment sample**–Values are in parts per million
- ——— **Boundary of geochemically anomalous area**
- - - - **Boundary of adjacent geochemically anomalous area**
- (2) **Number of geochemically anomalous area**
- ——— **Fault**—Approximately located
- ▒ **Glacier**

Figure 9. Geochemically anomalous stream-sediment and heavy-mineral-concentrate samples in the vicinity of Twin Falls Creek (geochemically anomalous area 2), Valdez 1°×3° quadrangle, Alaska. Area is underlain by rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

AREA 2—TWIN FALLS CREEK

Area 2 includes the Clear Creek, Anderson Glacier, and Twin Falls Creek watersheds along the north side of the Contact fault system (fig. 9). It is underlain mainly by sedimentary rocks of the Valdez Group, but, unlike area 3 immediately to the northeast, no gold-bearing quartz veins have been recognized in the area. Concentrate samples collected in area 2 during the Chugach survey contain anomalous amounts of arsenic, boron, copper, and tungsten on Clear Creek and arsenic, copper, and lead on Twin Falls Creek. At the former creek, values of 3,000 ppm As, 1,500 ppm Cu, and 15,000 ppm W correlate with the presence of abundant, microscopically visible arsenopyrite, chalcopyrite, and scheelite (R. Tripp, U.S. Geological Survey, 1983, unpub. data). Factor analysis indicates that AMRAP stream-sediment samples from the area are characterized by high scores onto factor 2, with highest positive loadings for copper and zinc. A NURE stream-sediment sample from Twin Falls Creek contains 139 ppm Cu and 13 ppm Sn, and one from the outwash from Anderson Glacier contains 350 ppm Cu, 212 ppm Cr, 19 ppm Pb, 31 ppm Sn, and 4.3 ppm U. No silver or gold anomalies were detected for samples from any of the geochemical surveys. The source for the anomalies is uncertain, but felsic igneous rocks and epigenetic sulfide-bearing quartz veins are suspected to be present in the area.

AREA 3—PORT VALDEZ MINING DISTRICT

Metasedimentary rocks of the Valdez Group and rare metavolcanic rocks and Tertiary intrusive stocks and dikes underlie area 3 (fig. 10). Area 3 contains the numerous mines and prospects of the Port Valdez gold district. Grab samples of gold-bearing quartz veins from the Alice, Cliff, Donohue, Giant and Upper Millionaire mines contain as much as 5,000 ppm Au, 700 ppm Ag, 11,000 ppm As, 62 ppm Bi, 17 ppm Cd, 1500 ppm Cu, >10 ppm Hg, 7,000 ppm Pb, 10 ppm Sb, 14 ppm W, and 710 ppm Zn (Goldfarb, 1989). The data reflect the presence of electrum, pyrite, chalcopyrite, galena, sphalerite, and arsenopyrite in the ore samples.

The boundary of area 3 is defined by anomalous gold in sediment samples and anomalous silver, gold, cobalt, copper, iron, nickel, or lead (±As, Mo, Zn) in concentrate samples. Factor analysis studies showed high factor 3 (Cu-Zn) scores for sediment samples and high factor 5 (Ag-Au-Cu-Pb) scores for concentrate samples. The anomalies are the product of gold and sulfide mineral grains weathered from the gold-bearing quartz veins of the Port Valdez district. These anomalies extend the borders of the district to include new favorable ground for mineral occurrences to the northwest and east. Anomalous concentrate samples from moraines along Divider Mountain and Pandora Peak, in the northwest part of area 3, indicate that gold-bearing veins are present at high elevations on Columbia Glacier. Jansons and others (1984) reported a small gold-bearing vein from the southern end of Divider Mountain. Gold anomalies along Sheep Creek define the probable eastern limit of the concentration of auriferous veins that compose the Port Valdez district.

A sample of metabasalt from the ridge southwest of Lake No 1 contains 5 ppm Au, 2,000 ppm Cu, >5,000 ppm Mn, 20 ppm Mo, and 500 ppm Zn (Miller and others, 1982). It is uncertain whether this reflects a syngenetic or epigenetic mineral occurrence; however, gold-, galena-, and chalcopyrite-bearing quartz veins of the Eagle prospect (V–78 in Jansons and others, 1984) are a few hundred meters to the northwest, and the metabasalt may have also interacted with the auriferous vein-forming fluids.

AREA 4—SOUTH PORT VALDEZ

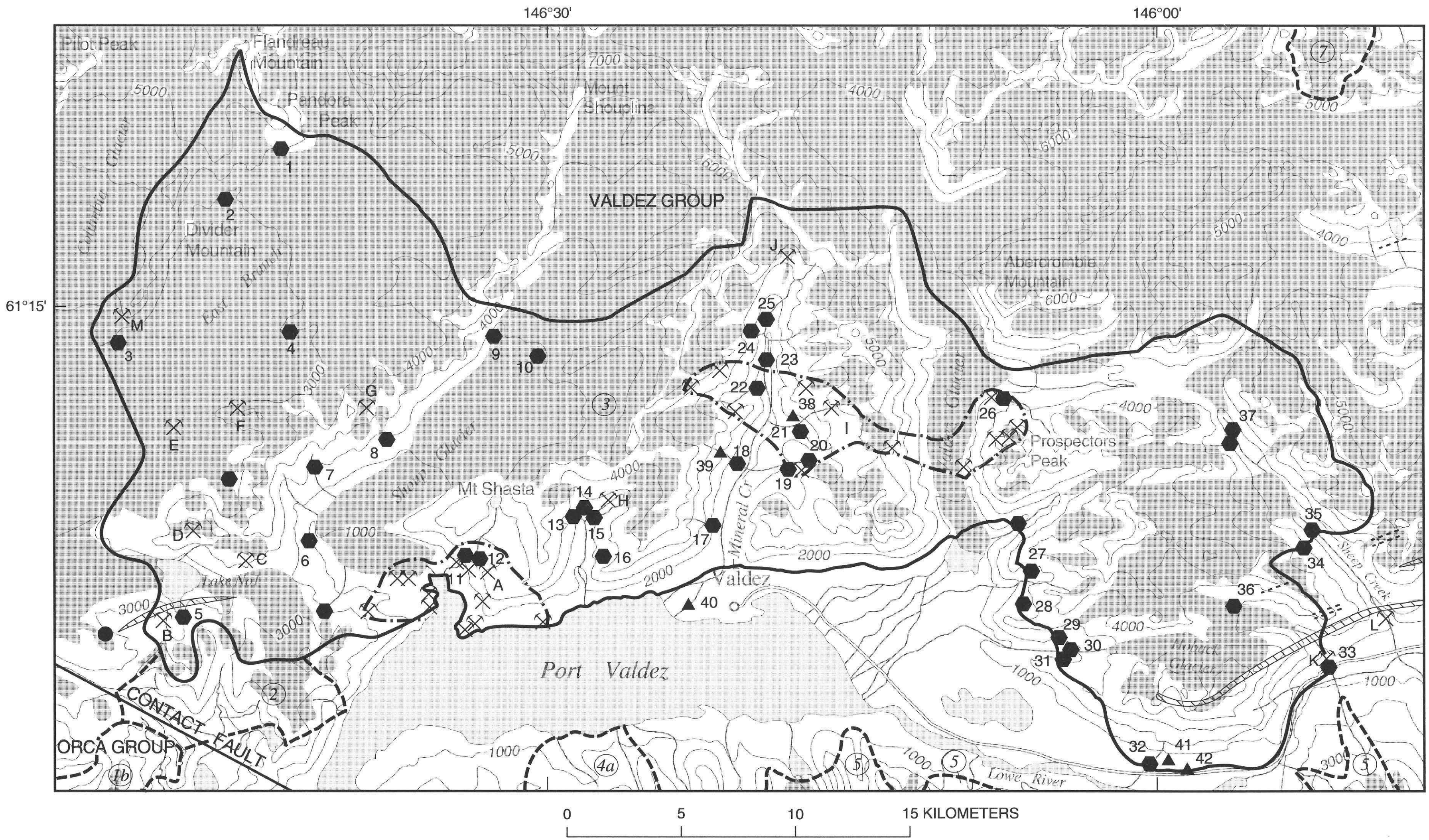
Two areas on south side of Port Valdez (areas 4a, 4b) underlain by metasedimentary rocks of the Valdez Group contain anomalous silver, arsenic, bismuth, and (or) lead in sediment and (or) concentrate samples collected during the Chugach National Forest survey (fig. 11). In the area between Port Valdez and Jack Bay (area 4a), within two north-facing watersheds, three concentrate samples contain as much as 15 ppm Ag, 10,000 ppm As, 30 ppm Bi, and 700 ppm Pb. South of the drainage divide, one sediment sample contains 40 ppm As and a second contains 100 ppm Pb and 160 ppm As. The corresponding concentrate for the latter sample also contains anomalous amounts of arsenic and lead. A few NURE stream-sediment samples to the northwest and south of area 4a contain anomalous amounts of uranium and thorium.

On the south shore of Jack Bay (area 4b), two sediment samples contain 70 ppm Pb and 40 and 80 ppm As, and the corresponding concentrate samples contain anomalous amounts of arsenic. The Curley-Kidney gold prospect (Johnson, 1919) is upstream in the delineated area. Gold-bearing quartz samples from the Orion prospect, about 3 km east of area 4b, contain as much as 26,000 ppm As, 300 ppm Cd, 16 ppm Sb, and 5,200 ppm Zn (R.J. Goldfarb, 1985, unpub. data). Area 4 is geochemically favorable for the discovery of additional small gold- and base-metal-bearing quartz veins.

AREA 5—CENTRAL SULFIDE BELT

The entire south-central margin of the Valdez quadrangle is characterized by concentrate samples from the AMRAP and Chugach surveys that contain anomalous amounts of base metals (fig. 12). Corresponding stream-sediment samples are rarely anomalous. This geochemically anomalous region (area 5) extends from Tasnuna Glacier on the east to Solomon Gulch on the west, and it represents the northern extent of the informally named central sulfide belt of the Cordova quadrangle to the south (Goldfarb and others, 1989). It is underlain by metasedimentary and metavolcanic rocks of the Valdez Group.

Concentrate samples from the AMRAP and Chugach National Forest geochemical surveys consistently contain anomalous amounts of silver, gold, cobalt, copper, iron, nickel, or lead. Some of these samples also have anomalous factor 2 scores. Bismuth is commonly anomalous in samples that have elevated lead concentrations, and tungsten is also anomalous at some sites. A sediment sample from the NURE survey collected on the south side of Heiden Canyon, 2.5 km east of Heiden Creek, contains 220 ppm Cu. The anomalies in area 5 reflect erosion of abundant pyrite, chalcopyrite, arsenopyrite, scheelite, and galena from upstream and upglacier metasedimentary and metavolcanic rocks of the Valdez Group. Lenses and disseminations of sulfide minerals, as well as sulfide-bearing quartz veins in shear zones, are common throughout area 5. Area 5 also contains the copper-rich massive sulfide orebodies of the Midas mine along Solomon Gulch, the Addison-Powell prospect reported in Sulphide Gulch, and the Wortmann Glacier sulfide occurrence (Winkler, Miller, and others, 1981). Ore samples from the Midas mine contain as


146°30'
146°00'
61°15'
Pilot Peak
Flandreau Mountain
Pandora Peak
Mount Shouplina
VALDEZ GROUP
Columbia Glacier
Divider Mountain
East Branch
Abercrombie Mountain
Shoup Glacier
Mt Shasta
Mineral Cr
Valdez Glacier
Prospectors Peak
Lake No1
Valdez
Port Valdez
Hoback Glacier
Sheep Creek
Lowe River
CONTACT FAULT
ORCA GROUP
1b
2
3
4a
5
7
0
5
10
15 KILOMETERS

EXPLANATION

Alaska Mineral Resource Assessment Program sample—Values are in parts per million except Fe which is in percent. Values are for concentrate samples except those accompanied by subscript "s," which are for sediment samples

1. Ag(5), Au(1.0), Co(100), Cr(1,000), Pb(500), Zn(500)
2. Ag(7), Au(30), Co(100), Cu(700)
3. Ag(5), Au(0.6), Cu(700), Pb(500)
4. Ag(7), Au(0.45), Co(100), Cu(700), Fe(20), Pb(500)
5. Ag(3), Pb(700)
6. Ag(7), Co(100), Cu(500), Fe(20), Pb(500)
7. Au_s(0.65)
8. Cu(700), Fe(20), Au_s(0.35)
9. Ag(5), Cu(700), Fe(20), Pb(500), Au_s(0.15)
10. Ag(7), Cu(700), Pb(500), Au_s(0.10)
11. Ag(7), Au(26), Cu(1,000), Pb(500), Au_s(0.10)
12. Ag(10), As(<500), Au(8.5), Co(100), Cu(1,000), Fe(20), Ni(300), Pb(500)
13. Ag(5), Au(35), Cu(500), Pb(500), Au_s(0.05)
14. Ag(5), Cu(700), Pb(700)
15. Ag(10), As(500), Cu(700), Ni(500), Pb(500)
16. Au(3.5), Pb(300), Au_s(0.10)
17. Au(3.5), Pb(7,000)
18. Ag(7), As(500), Co(100), Cu(700), Fe(20), Ni(300), Zn(400), Au_s(0.10)
19. Ag(10), Au(44), Cu(500), Pb(300), Au_s(0.15)
20. Ag(5), Au(12), Cr(1,000), Cu(500), Pb(700), Au_s(0.05)
21. Ag(2), Au(100), Fe(20), Zn(240)
22. Ag(7), As(500), Au(2.5), Co(100), Cu(700), Ni(500), Pb(500), Zn(2,000), Au_s(0.25)
23. Au_s(0.05), Pb_s(100)
24. Ag(5), Co(100), Cu(700)
25. Ag(5), Cu(500), Zn(300)
26. Ag(3), Au(12), Au_s(0.05)
27. Au(0.5), Cu(500), Au_s(0.05)
28. Cu(500), Au_s(0.10)
29. Au_s(0.05)
30. Ag(5), As(<500), Au(5.5), Pb(500), Au_s(0.85)
31. Au_s(0.20)
32. Cu(500)
33. As(<500), Au(4), Cu(700)
34. Ag(20), As(700), Au(1.5), Cu(700), Pb(2,000), Au_s(0.10)
35. Ag(3), Au(2), Cu(1,500), Zn(260)
36. Au(0.85)
37. Au_s(0.10)

Alaska Mineral Resource Assessment Program sample of metabasalt containing anomalous Au(5.0 ppm), Cu(2,000 ppm), Mn(>5,000 ppm), Mo(20 ppm), and Zn(500 ppm)

Mines and prospects

- A. Big Four, Palmer, I.X.L., Shoup Bay Mining Co., Silver Gem, Spanish, Bluebird, Whistler, Cube, Alice, Seacoast Mining Co., Bunker Hills, Cliff, Gold-Bluff, Gutherie and Belloli, Gold Creek, Hecla, Sealy-Davis
- B. Eagle
- C. Bessie Williams
- D. National, Mayfield
- E. Rough and Tough
- F. Gold King
- G. Cameron-Johnson
- H. McCallum
- I. Big Four, Hercules, Chesna, Monte Carlo, Sunshine, Slide, Millionaire, Forty Five, July, High Grade, Alaskan, Mountain View, Ethel, Blue Ribbon, Valdez Bonanza, Rose Johnson, Donohue, Rose, Ramsay-Rutherford, Star, Pinochle, Little Giant, Mountain King, Valdez
- J. Quitsch
- K. Wortmanns
- L. Sheep Creek
- M. Gold-bearing quartz-vein occurrence

Anomalous National Uranium Resource Evaluation sediment sample—Values are in parts per million

38. Au(0.83)
39. Au(0.53)
40. Au(0.58)
41. Pb(69)
42. Pb(27)

Boundary of geochemically anomalous area

Boundary of adjacent geochemically anomalous area

(3) **Number of geochemically anomalous area**

Boundary of region containing abundant mines and prospects

Richardson Highway

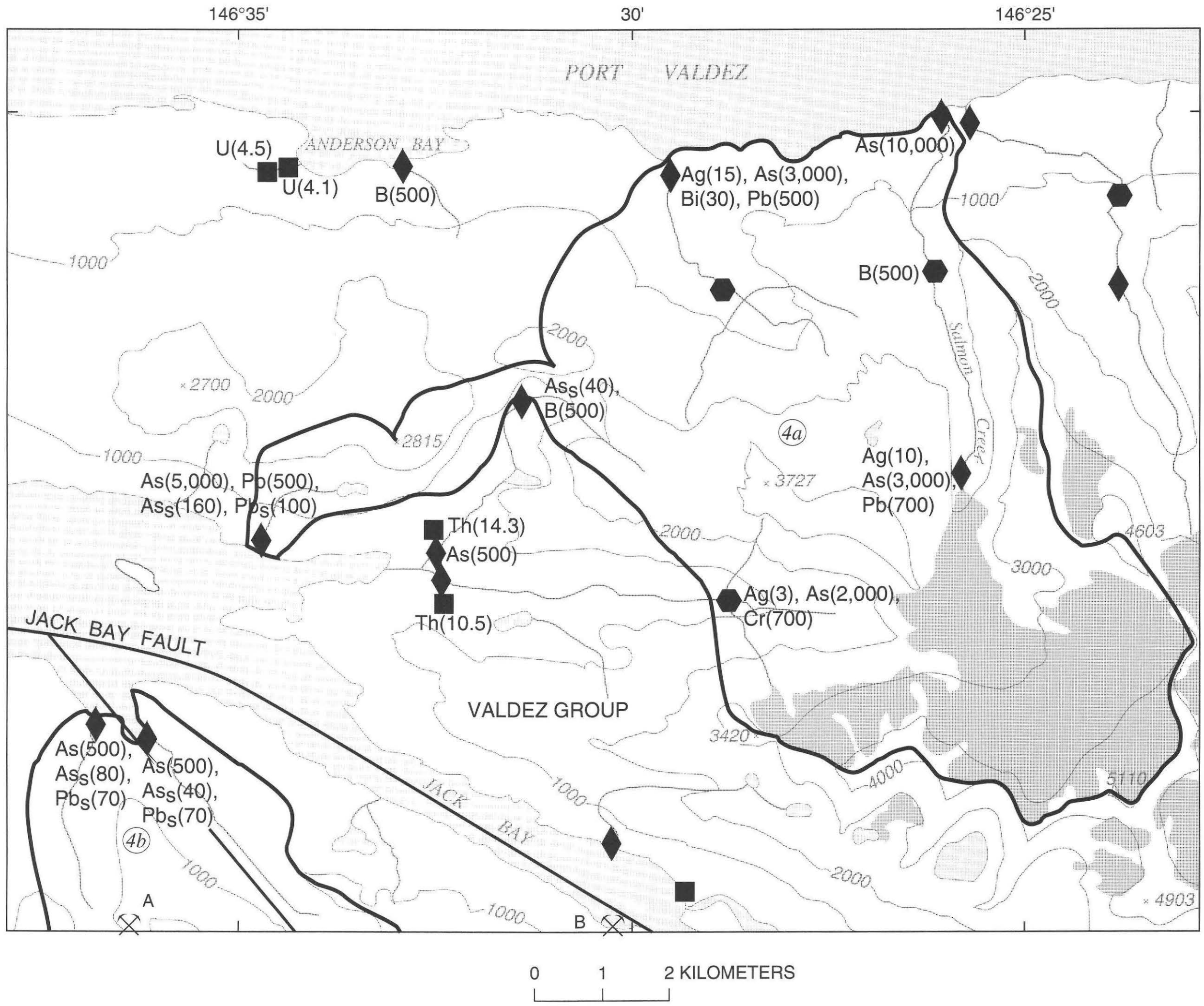
Metavolcanic rocks

Tertiary felsic dike swarm

Fault—Approximately located

Glacier

Figure 10. Geochemically anomalous stream-sediment, heavy-mineral-concentrate, and rock samples in and adjacent to the Port Valdez mining district (geochemically anomalous area 3), Valdez 1°×3° quadrangle, Alaska. Area is underlain by rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.



EXPLANATION

⬢ **Alaska Mineral Resource Assessment Program concentrate sample**—Values are in parts per million

◆ **Chugach National Forest Survey sample**—Values are in parts per million. Values are for concentrate samples except those accompanied by subscript "s," which are for sediment samples

■ **National Uranium Resource Evaluation sediment sample**—Values are in parts per million

Boundary of geochemically anomalous area

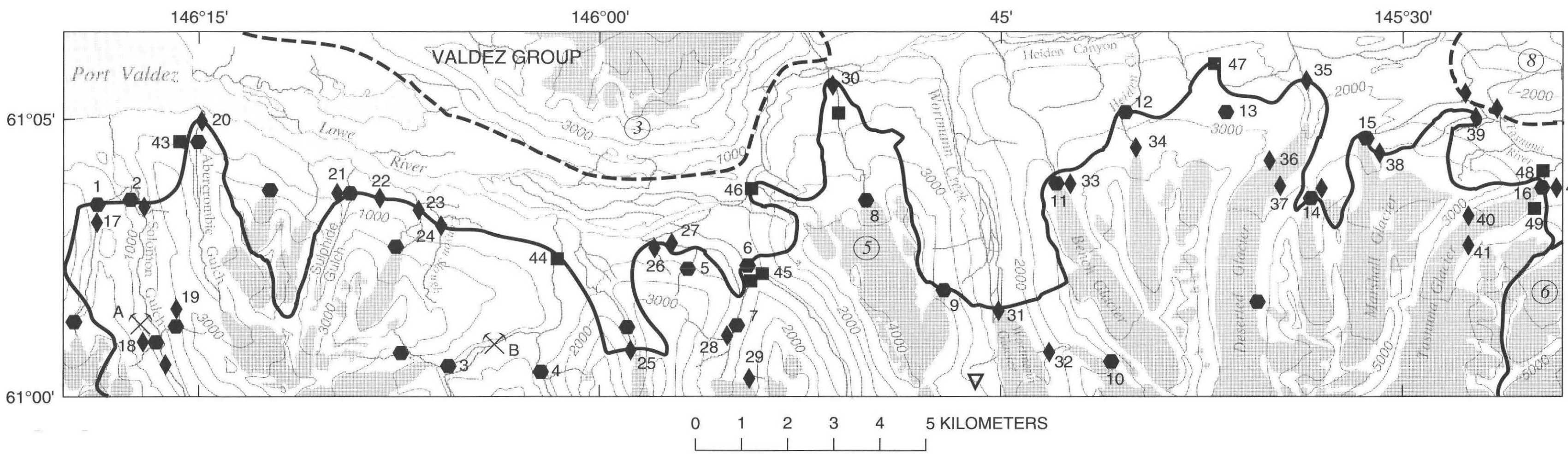
(4a) **Number of geochemically anomalous area**

⚒ **Prospects**—A, Curley-Kidney prospect; B, Orion prospect

Fault—Approximately located

Glacier

Figure 11. Geochemically anomalous stream-sediment and heavy-mineral-concentrate samples south of Port Valdez (geochemically anomalous areas 4a and 4b), Valdez 1°×3° quadrangle, Alaska. Area is underlain by rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.



EXPLANATION

● **Alaska Mineral Resource Assessment Program sample**—Values are in parts per million except Fe, which is in percent. Values are for concentrate samples except those accompanied by subscript "s," which are for sediment samples

1. Pb_s(100)
2. Cr_s(700)
3. Ag(2), Co(700), Cr(1,000)
4. Cu_s(200)
5. Au(2.5), Cu(500), Au_s(0.15)
6. Cu(500)
7. Pb(500)
8. Cu(500)
9. Cu(500)
10. Au_s(0.10)
11. Cu(500), Mn(5,000)
12. Cu(500), Mn(3,000)
13. Cu(500), Fe(20), Mn(>5,000)
14. As(<500), Au(0.90), Cu(500), Fe(20), Mn(>5,000)
15. Ag(10), As(1,000), Co(200), Cu(1,000), Fe(20), Mn(>5,000), Ni(300), Pb(5,000), Au_s(0.25), Mn_s(3,000), Pb_s(70)
16. Co(100), Cu(500), Fe(20)

♦ **Chugach National Forest Survey sample**—Values are in parts per million except Fe, which is in percent. Values are for concentrate samples except those accompanied by subscript "s," which are for sediment samples

17. Ag(2), As(2,000), Pb(500)
18. As(2,000)
19. As(2,000), Co(500), Cu(500), Fe(30), Ni(700), Zn_s(200)
20. Ag(70), As(10,000), Bi(150), Co(500), Fe(20), Pb(3,000)
21. Ag(200), As(5,000), Au(1,000), Bi(70), Co(700), Cu(1,000), Fe(50), Pb(3,000)
22. As(3,000), B(500), Pb(1,500)
23. As(3,000), Pb(300)
24. Ag(100), Au(700), W(200)
25. Co(150), Cu(20,000)
26. W(500)
27. Ag(10), As(20,000), Bi(50), Co(1,000), Cu(3,000), Fe(50), Ni(700), Pb(1,500)
28. Pb(500)
29. As(20,000), Ba(2,000), Be(15), Cu(500), Fe(30), Mn(3,000), V(1,000)
30. Ag(10), As(15,000), Co(200), Cu(700), Pb(1,000)
31. As(2,000), Co(500), Cu(3,000), Fe(20), Cu_s(300)
32. Ag(15), As(15,000), Co(200), Cu(2,000), Pb(1,500), W(700)
33. Ag(20), As(5,000), Bi(100), Co(700), Cu(1,000), Mn(3,000), Ni(500), Pb(2,000), W(100)
34. Ag(15), As(>20,000), Bi(50), Co(300), Cu(1,500), Pb(1,500), W(100)
35. As(1,500), Co(500), Cu(1,500), Fe(20), Pb(300)
36. Ag(20), As(20,000), Au(200), Cu(700), Mn(3,000), Pb(300), W(200)
37. Co(300), Cu(700)
38. Ag(7), As(3,000), Co(200), Cu(1,500), Mn(5,000), Pb(500)
39. Ag(20), As(1,500), Au(20), B(500), Bi(70), Co(300), Cu(5,000), Ni(500), Pb(3,000), Sb(500), Mn_s(3,000), Pb_s(150)
40. As(500), Co(300), Fe(30)
41. As(1,000), Be(5), Cu(1,000), W(500)
42. Ag(7), As(5,000), Co(300), Cu(700), Fe(50), Ni(300), Pb(500), W(500)

■ **National Uranium Resource Evaluation sediment sample**—Values are in parts per million

43. Au(3.26), Ba(1,037)
44. Cd(5), Cr(243)
45. Au(0.1)
46. W(15)
47. Co(34.5), Cr(206), Cu(220)
48. Cd(5), Mn(2,049)
49. Cu(117), Mn(3,960), Pb(21)

⚒ **Mine or prospect**—A, Midas mine; B, Addison-Powell prospect. Approximately located

▽ **Wortmann Glacier occurrence**

—— **Boundary of geochemically anomalous area**

- - - - **Boundary of adjacent geochemically anomalous area**

(5) **Number of geochemically anomalous area**

▒ **Glacier**

Figure 12. Geochemically anomalous stream-sediment and heavy-mineral-concentrate samples along the southern margin of the Valdez quadrangle, between Tasnuna Glacier and Solomon Gulch (geochemically anomalous area 5) (central sulfide belt), Valdez 1°×3° quadrangle, Alaska. Area is underlain by rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

much as 150 ppm Ag, 10 ppm Au, 200 ppm Cd, 8.5 percent Cu, 10 percent Fe, 200 ppm Pb, and 4 percent Zn. Hornfels and metavolcanic rocks at the Wortmann Glacier occurrence are characterized by values of as much as 1.5 ppm Ag, 500 ppm Cr, 1,500 ppm Cu, 15 percent Fe, 7 percent Mg, 300 ppm Pb, and 7,000 ppm Zn (Miller and others, 1982).

Rose (1965) collected about 80 stream-sediment samples in the Solomon Gulch–Sulphide Gulch area. These were all analyzed by atomic abosorption for copper, molybdenum, lead, and zinc. Samples from Sulphide Gulch contained as much as 700 ppm Cu, indicative of the abundant small veinlets and lenses of chalcopyrite within the watershed. Within Solomon Gulch, a sample collected immediately downstream from the Midas mine dump contained 1,150 ppm Cu and 245 ppm Zn; however, a sediment sample collected less than 100 m north and from a creek draining the same west wall of Solomon Gulch contained only 40 ppm Cu and 125 ppm Zn. The only sediment sample collected along the main channel of Solomon Gulch, about 5 km downstream from the dump, also contained background concentrations of copper and zinc. Sutley and others (1990), studying a similar type of massive sulfide occurrence 10 km south of the Valdez quadrangle near Ellamar, noted that these types of mineral occurrences produce poor clastic dispersion patterns. Therefore, they may be difficult targets to identify using stream-sediment surveys.

Anomalous gold was detected in concentrate and sediment samples from a number of sites in area 5. Concentrate samples collected on the south side of the road below Sulphide Gulch and below a tributary to Canyon Slough 3.5 km to the east contain 1,000 and 700 ppm Au, respectively. Gold was also detected in a concentrate collected from the lateral moraine on the west side of Deserted Glacier. A concentrate sample collected from the glacial outwash below Marshall Glacier, immediately above its junction with the headwaters of the Tasnuna River, is enriched in gold and also contains 500 ppm Sb. This is the only concentrate in the Valdez quadrangle, from either the Chugach or AMRAP reconnaissance surveys, that contains measurable amounts of antimony (as determined by emission spectrography). The corresponding stream-sediment sample contains 150 ppm Pb. Microscopic examination of these four concentrate samples collected during the Chugach survey confirmed the presence of gold grains (Tripp and others, 1985). Samples containing anomalous gold collected during the AMRAP survey include a concentrate from the toe of the unnamed glacier between Deserted and Marshall Glaciers, a moraine sediment containing 0.1 ppm Au from an unnamed glacier between Bench and Wortmann Glaciers, and a stream sediment containing 0.25 ppm Au from the toe of Marshall Glacier. A stream-sediment sample from the mouth of Abercrombie Gulch, collected during the NURE survey, contains 3.26 ppm Au.

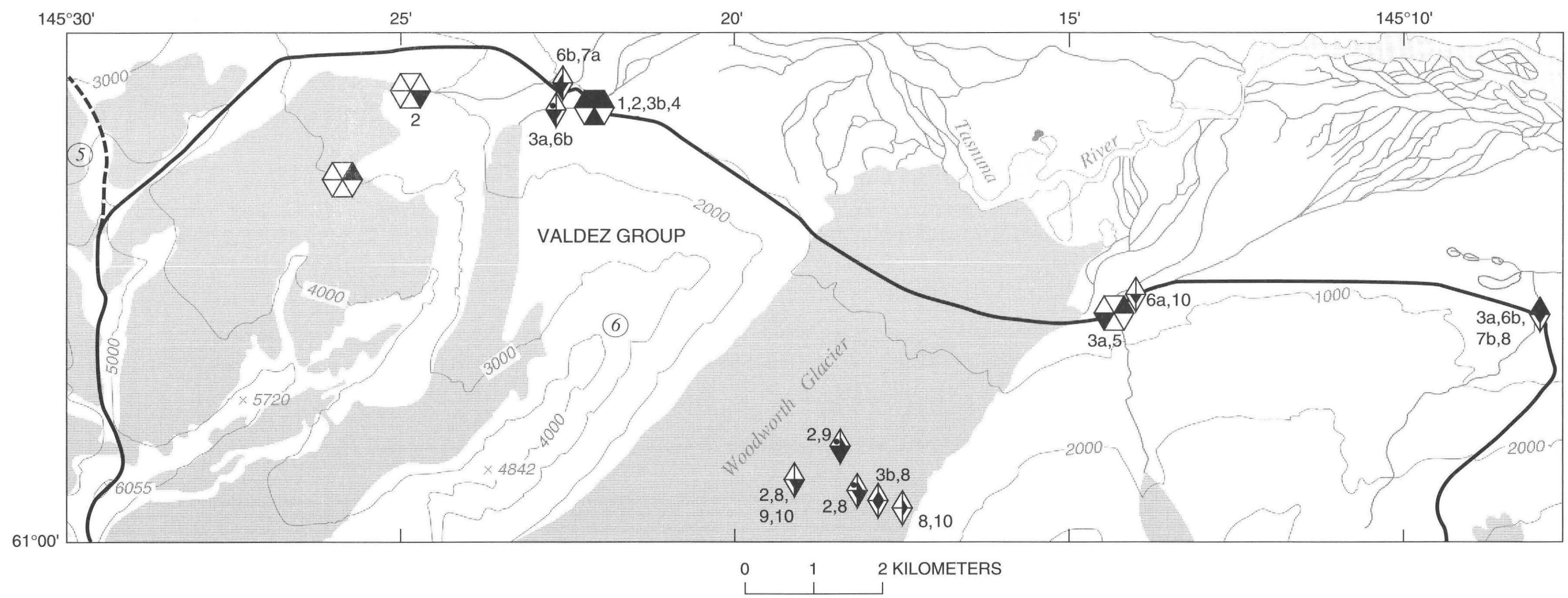
Three concentrate samples collected during the AMRAP survey between Bench and Marshall glaciers and six others collected within a few kilometers to the north and east contain 5,000 ppm or more Mn. These concentrates also have high scores onto factor 4, and the most positive factor loading is for manganese. A corresponding stream-sediment sample below Marshall Glacier contains 3,000 ppm Mn. At approximately the same location, a concentrate sample collected during the Chugach National Forest survey contains 5,000 ppm Mn. Two NURE sediment samples collected near the toe of Tasnuna Glacier have anomalous manganese contents of 2,049 ppm and 3,960 ppm. These samples reflect the northern extent of a broad belt of anomalous manganese described to the south of the Chugach Mountain crest in the Cordova quadrangle and within the Gravina River watershed (area 17 of Goldfarb and others, 1989).

The source for the anomalous manganese is uncertain, but the presence of bedded manganese within rocks of the Valdez Group, especially in spatial association with metavolcanic units, is one possibility. A more likely source may simply be metasedimentary rocks of the Valdez Group that locally contain high background amounts of manganese. Samples of schist and phyllite on the north side of Cleave Creek Glacier, to the northeast of area 5, both contain more than 5,000 ppm Mn.

AREA 6—WOODWORTH GLACIER

The Woodworth Glacier area is underlain by metasedimentary rocks of the Valdez Group (fig. 13); however, metavolcanic rocks are interbedded with these rocks along Woodworth Glacier, a few kilometers to the south in the Cordova quadrangle (Winkler and Plafker, 1981). Four of five stream-sediment samples collected during the Chugach survey from medial moraines 3–4 km above the toe of the glacier contain 150–200 ppm Cu. The five corresponding concentrate samples contain anomalous amounts of silver, boron, cobalt, copper, and iron (±Bi, Ni, Pb, W). Jansons and others (1984) reported shear zones in metavolcanic rocks along Woodworth Glacier, 6 km south of the Valdez quadrangle boundary, that contain chalcopyrite in quartz veins. Quartz veins in the area also contain pyrite, galena, and sphalerite. The geochemical anomalies, reflecting an abundance of iron- and copper-sulfide minerals in the morainal material, are probably the result of weathering of similar types of material.

Concentrate samples collected downstream from smaller glaciers to the east and west of Woodworth Glacier also contain anomalous amounts of silver and copper but contain background concentrations of cobalt, iron, and nickel. These samples collected during the Chugach survey also contain anomalous amounts of arsenic, gold,



EXPLANATION

Ag, Cu_s, Cu, Co — **Chugach National Forest Survey sample**—Values are in parts per million. Values are for concentrate samples except those accompanied by subscript "s," which are for sediment samples. Leaders (--), no value for that category

Category	Map symbol	Ag	Cu_s	Co	Cu
Slightly anomalous.	•	1–7	--	--	--
Moderately anomalous.	◢ (small)	10–20	150–200	100–200	500–1,000
Highly anomalous.	◢ (large)	500	--	700–1,500	1,500–3,000

Additional anomalous values: 2, Fe(20–30); 3, Pb(a=500–700, b=1,000–1,500); 6, As(a=500–700, b=5,000–7,000); 7, Au(a=150, b=1,000); 8, B(500–1,000); 9, Ni(300); 10, W(150–500)

As, Au, Mn, Cu, Au_s, Ag — **Alaska Mineral Resource Assessment Program sample**—Values are in parts per million except Fe, which is in percent. Values are for concentrate samples except those accompanied by subscript "s," which are for sediment samples

Category	Map symbol	As	Au	Mn	Cu	Au_s	Ag
Anomalous	▼	1,500	0.6–4.0	5,000	700	0.25	30

Additional anomalous values: 1, Co(300); 2, Fe(20–30); 3, Pb(a=500–700, b=1,000–1,500); 4, Zn(400); 5, Pb_s(70)

—— **Boundary of geochemically anomalous area**

- - - - **Boundary of adjacent geochemically anomalous area**

(6) **Number of geochemically anomalous area**

Glacier

Figure 13. Geochemically anomalous stream-sediment and heavy-mineral-concentrate samples on moraines and within adjacent valleys to Woodworth Glacier (geochemically anomalous area 6), Valdez 1°×3° quadrangle, Alaska. Area is underlain by metasedimentary rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

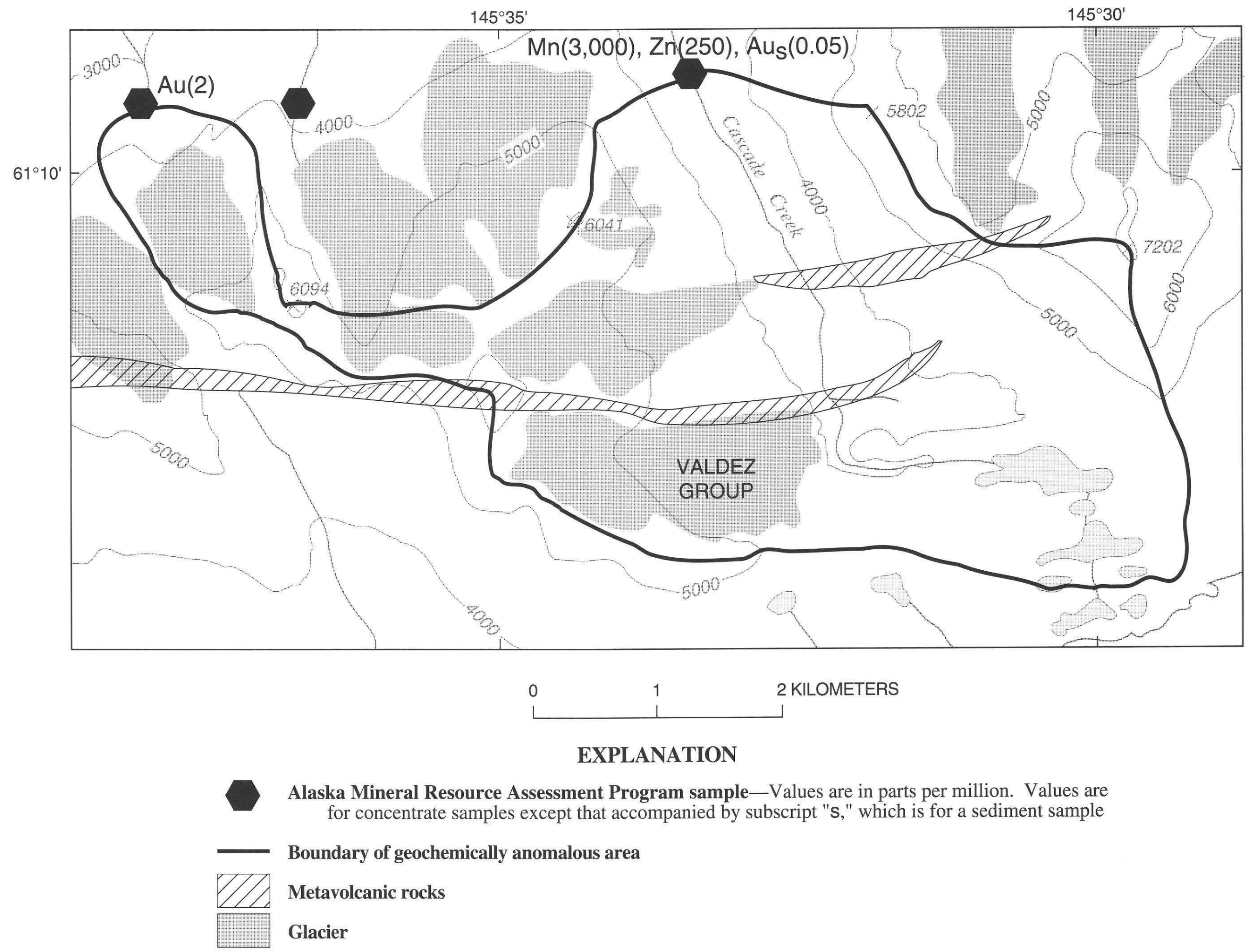


Figure 14. Geochemically anomalous stream-sediment and heavy-mineral-concentrate samples from Cascade Creek and an adjacent stream channel (geochemically anomalous area 7), Valdez 1°×3° quadrangle, Alaska. Area is underlain by metasedimentary rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

and lead (±Bi, W). Two of the sample sites were previously sampled during the AMRAP survey, and both resulting concentrate samples and one stream-sediment sample contain anomalous gold. These results suggest greater precious-metal favorability in the smaller glacier-filled valleys as compared to the main valley occupied by Woodworth Glacier.

AREA 7—CASCADE CREEK

A sediment sample from Cascade Creek contains 0.05 ppm Au and the corresponding concentrate sample contains 250 ppm Zn, and a concentrate sample 4–5 km to the west contains 2 ppm Au (fig. 14). The samples were collected from watersheds mainly underlain by metasedimentary rocks of the Valdez Group, but minor metavolcanic rocks are also exposed. The source for the anomalies is uncertain.

AREA 8—CLEAVE CREEK GLACIER

Concentrate samples collected during the AMRAP and Chugach surveys from an extensive area centered around Cleave Creek Glacier and underlain mostly by metasedimentary rocks of the Valdez Group consistently contain anomalous amounts of silver, arsenic, and gold (fig. 15). The highest concentrations for these elements, in samples collected near the toe of Cleave Creek Glacier during the Chugach survey, are 700 ppm Ag, >20,000 ppm As, and >1,000 ppm Au. Concentrate samples from area 8 also contain as much as 20–30 percent Fe, 5,000 ppm B, 10 ppm Be, 200 ppm Bi, 2,000 ppm Co, 1,500 ppm Cu, 700 ppm Ni, 15,000 ppm Pb, 30 ppm Sn, 700 ppm W, and 1,000 ppm Zn. Factor analysis studies show that most of these concentrates also have high scores onto factor 5, dominated by silver, gold, lead, and copper. The majority of the samples that have anomalous base-metal values and anomalous factor 2 scores (dominated by copper, nickel, and iron) are restricted to channels draining the north side of area 8. Some of these drainages contain mafic metavolcanic rocks in their headwaters. Anomalous antimony also characterizes the sample from the toe of Cleave Creek Glacier. Microscopically visible gold and base-metal sulfide grains are relatively abundant in many of the samples.

In contrast to concentrate samples, stream- and moraine-sediment samples are mostly ineffective in helping to define area 8. None of the 30 sediment samples collected during the Chugach survey contains elevated amounts of base- or precious-metals; however, the lower analytical determination limit for gold in that survey is 10 ppm using only emission spectrography. Five of twenty-five sediment samples collected from the AMRAP survey contain 0.05–1.0 ppm Au, as determined by atomic-absorption analysis. The sediment sample containing 1.0 ppm Au is from the northwest corner of area 8. A sediment sample containing 0.5 ppm Au is from below the north-facing glacier about 1 km south of the toe of Cleave Creek Glacier. A NURE stream sediment collected near the toe of Cleave Creek Glacier contains 0.57 ppm Au. The only NURE lake-sediment sample containing detected gold (0.17 ppm) was collected in the watershed south of Jackson Creek at about 762 m elevation.

Additionally, four sediment samples from the AMRAP survey scattered across area 8 contain 3,000 ppm Mn. Concentrate samples from area 8 have high scores onto factor 4, and manganese is the most positively loaded element. Samples of schist and phyllite from area 8 both contain more than 5,000 ppm Mn (Miller and others, 1982), suggesting a high background for manganese in that part of the Valdez Group.

AREA 9—EAST SIDE OF THE COPPER RIVER

A large area on the east side of the Copper River is defined by heavy-mineral-concentrate samples that contain anomalous amounts of gold and, less commonly, silver or arsenic (fig. 16). Except for a few thin units of mafic metavolcanic rocks, the entire area is underlain by metasedimentary rocks of the Valdez Group. Although no lode mineral occurrences have been recognized in area 9, a placer gold prospect was reported along the west fork of the Little Bremner River (Moffit, 1914), and a quartz vein from the ridge northeast of peak 7290 contains 200 ppm As (Miller and others, 1982).

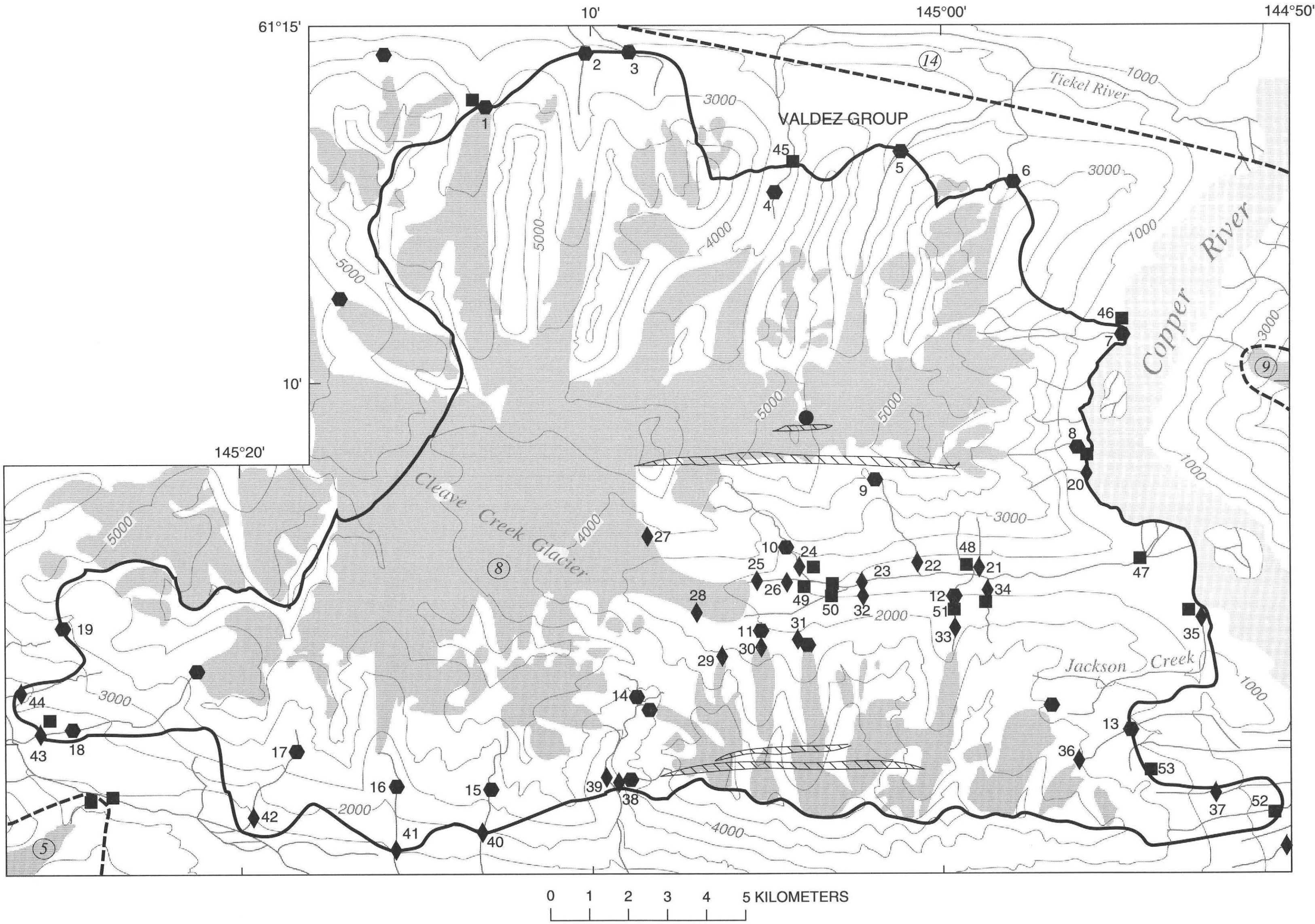
Eleven AMRAP concentrate samples from area 9 contain anomalous amounts of gold. A maximum reported value in area 9 of 24 ppm Au is for a concentrate sample collected from the glacial outwash sediment along the north edge of the area and about 1 km west of peak 6890. Anomalous amounts of silver are present in three concentrate samples from the area (two of which also contain anomalous gold), and arsenic is anomalous in three other concentrate samples. Stream-sediment samples are less consistently anomalous in gold. Seven of the AMRAP samples contain 0.05–0.3 ppm Au. Three NURE stream-sediment samples along the eastern edge of the area contain 0.16–0.3 ppm Au, and one along Dewey Creek contains 1.13 ppm Au. The concentrate and sediment anomalies are probably derived from small precious-metal-bearing quartz veins scattered throughout the rocks of the Valdez Group.

Six of the concentrate samples from the southern half of area 9 contain 5,000 ppm or more Mn and have anomalous factor 4 scores. Corresponding stream-sediment samples contain only 1,000–2,000 ppm Mn. The anomalies are of similar magnitude and likely have a source similar to those described previously for area 5 and the area to its south within the Gravina River watershed in the Cordova quadrangle. In both cases, the source for the anomalous manganese is uncertain.

In addition to containing anomalous amounts of silver and gold, the concentrate sample collected from the medial moraine 1 km east of peak 6840 contains anomalous amounts of many other metals. The sample contains 20 percent Fe, 100 ppm Co, 700 ppm Cu, 20 ppm Mo, 300 ppm Ni, 500 ppm Pb, and 460 ppm Zn. These data suggest the presence of some type of sulfide-rich mineral occurrence on the source nunatak. The presence of mafic volcanic rocks within the nunatak (Winkler, Silberman, and others, 1981) suggests the potential for volcanogenic sulfide occurrences.

AREA 10—BREMNER RIVER

NURE stream-sediment samples from the south side of the Bremner River consistently contain anomalous amounts of rare earth elements (fig. 17). The area is underlain entirely by metasedimentary rocks of the Valdez Group. Four samples contain 5.2–7.2 ppm U. One of these has a thorium concentration of 16.4 ppm, the highest from the NURE survey, and another has the highest measured cesium, dysprosium, and samarium values. Other rare earth elements are also enriched in many of the samples. Similar NURE anomalies are present immediately to the south of area 10, in the Cordova quadrangle, where Goldfarb and others (1989) reported uranium values of as much as 30 ppm and thorium values of as much as 89 ppm. The presence of monazite, apatite, allanite, and other accessory minerals in the high-grade metamorphic rocks of the high-temperature, low-pressure Chugach metamorphic complex (Hudson and Plafker, 1982), immediately to the south of the Valdez quadrangle, is believed to be the cause of the anomalies. Therefore rare earth element anomalies in area 10 are not of economic interest.


61°15'
10'
145°00'
144°50'
145°20'
61°05'
VALDEZ GROUP
Tiekel River
Copper River
Cleave Creek Glacier
Jackson Creek
1000
2000
3000
4000
5000
0 1 2 3 4 5 KILOMETERS

EXPLANATION

Alaska Mineral Resource Assessment Program sample—Values are in parts per million. Values are for concentrate samples except those accompanied by subscript "s," which are for sediment samples

1. Ag(10), As(700), Au(20), Cr(1,000), Cu(1,500), Fe(20), Pb(1,500), W(<100), Zn(380), Au_S(1.0)
2. Cu(700), Fe(20)
3. Cr(1,000)
4. Ag(5), As(500), Cu(700), Fe(20), Pb(700), W(<100), Au_S(0.10)
5. Ag(7), As(1,500), Au(7.5), Co(100), Cu(1,000), Fe(20), Pb(700), Zn(1,000)
6. Cu(500), Fe(20)
7. Ag(7), As(<500), Cu(1,000), Pb(500), Zn(350)
8. Au(0.5), Mn_S(3,000)
9. Mn(5,000)
10. Be_S(1.5)
11. Au(6.5), Mn(5,000), Au_S(0.5), Mn_S(3,000)
12. As(<500), Mn(3,000)
13. Mn(3,000), Au_S(0.05)
14. As(700), Au(5.5)
15. Be_S(1.5)
16. Au(8)
17. Au(0.5), Cu(500), Fe(20), Mn(>5,000), Mn_S(3,000)
18. Fe(20), Mn(5,000)
19. Mn(>5,000), Au_S(0.05), Mn_S(3,000)

Alaskan Mineral Resource Assessment Program rock sample location—Values are in parts per million. Phyllite: Cu(300), Mn(>5,000), Pb(100), Zn(300). Schist: Au(0.05), B(1,500), Cu(200), Mn(>5,000)

Chugach National Forest Survey concentrate sample—Values are in parts per million

20. As(500), W(100)
21. As(500)
22. Ag(5), As(7,000), Au(20), Co(100)
23. Ag(70), As(>20,000), Au(30), Bi(100), Co(1,500), Ni(500), Pb(5,000), Zn(1,000)
24. Ag(7), As(7,000), Au(70), B(500), Co(150), W(200)
25. Ag(700), As(>20,00), Au(>1,000), B(1,000), Bi(100), Co(1,000), Fe(20), Ni(300),Pb(5,000)
26. Ag(700), As(>20,000), Au(>1,000), B(1,000), Bi(200), Co(2,000), Cu(1,000), Fe(30), Ni(700), Pb(15,000), Sb(<200),W(500)
27. Ag(70), As(5,000), Au(300), B(700)
28. Ag(7), As(1,500), B(2,000), Pb(700)
29. As(3,000)
30. Ag(7), As(7,000), B(1,500), Co(300), Pb(500)
31. Ag(7), As(5,000), Au(70), B(1,000), Co(100), Cu(500)
32. Ag(30), As(>20,000), B(2,000), Ba(2,000), Bi(50), Co(700), Ni(300), Pb(1,000), W(700)
33. As(3,000), B(500)
34. Ag(50), As(>20,000), Au(100), B(1,000), Co(200), Pb(700), W(700)
35. Ag(7), As(7,000), B(700), W(200)
36. As(5,000), B(700)
37. As(500)
38. Ag(7), As(3,000), B(5,000), Be(10), Co(100), Pb(500)
39. Ag(20), As(10,000), Au(150), B(500), Co(100), Sn(20)
40. Sn(30)
41. Ag(7), As(10,000), B(500), Co(200), Pb(700)
42. B(3,000), W(100)
43. Ag(7), As(2,000), Au(70), B(500)
44. As(3,000)

National Uranium Resource Evaluation sediment sample—Values are in parts per million, except Fe, which is in percent. Values are for stream-sediment samples except that accompanied by subscript "L," which is for a lake-sediment sample

45. Au(0.24)
46. Fe(8.1), Sn(17)
47. Bi(5), U(4.0)
48. Bi(5)
49. Pb(16)
50. Au(0.57)
51. U(4.6)
52. Bi(5)
53. Au_L(0.17)

Boundary of geochemically anomalous area

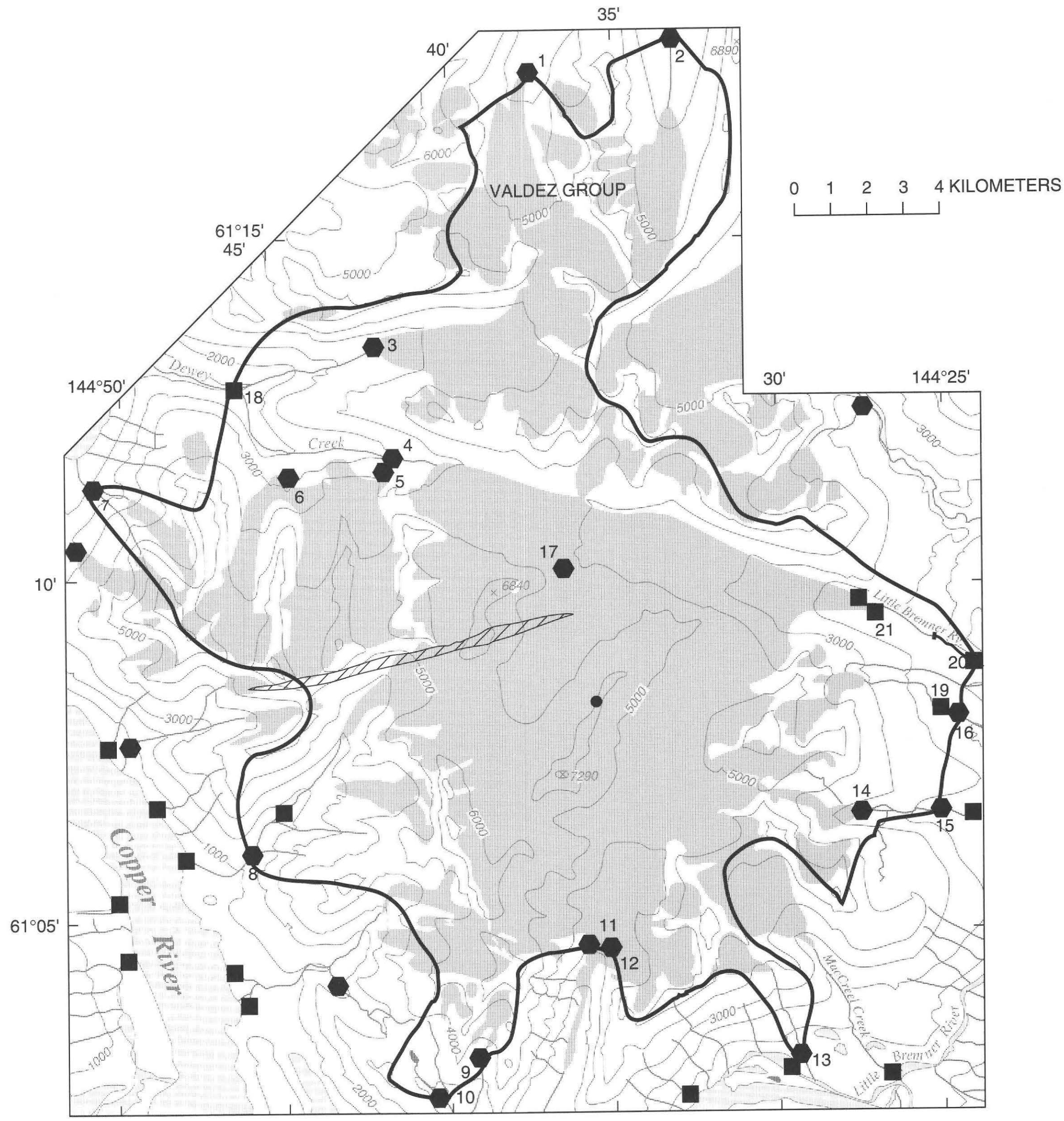
Boundary of adjacent geochemically anomalous area

(8) **Number of geochemically anomalous area**

Mafic metavolcanic rocks

Glacier

Figure 15. Geochemically anomalous stream-sediment, lake-sediment, heavy-mineral-concentrate, and rock samples within the Cleave Creek Glacier watershed and valleys to the north and south (geochemically anomalous area 8), Valdez 1°×3° quadrangle, Alaska. Area is underlain mostly by metasedimentary rocks of the Valdez Group of the Chugach terrane. Base map is from U.S. Geological Survey Valdez 1960, scale 1:250,000. Contour interval is 1,000 feet.



EXPLANATION

Alaska Mineral Resource Assessment Program sample—Values are in parts per million. Values are for concentrate samples except those accompanied by subscript "s," which are for sediment samples

1. Au(1)
2. Ag(5), Au(24), Cr(1,000), W(<100)
3. Au(2.3)
4. Au(3.5), Cu(500), Au_s(0.2)
5. Au(14)
6. As(<500), Cu(500), Au_s(0.3)
7. As(500)
8. As(700), Cu(500), Mn(3,000), Au_s(0.1), Mn_s(3,000)
9. Cu(500), Mn(>5,000), Au_s(0.1)
10. Au(8), Cu(500), Mn(5,000), Zn(<500), Au_s(0.1)
11. Au(2), Ba(2,000), Mn(>5,000)
12. Ba(2,000), Mn(5,000)
13. Au(1.5), Mn(>5,000)
14. Au(2), Mn(>5,000), Au_s(0.05)
15. Au(5), Au_s(0.2)
16. Ag(5), Cu(500), Fe(20), Pb(300), Mo(<10)
17. Ag(7), Au(0.5), Co(100), Cu(700), Fe(20), Mo(20), Ni(300), Pb(500), Zn(460)

National Uranium Resource Evaluation sediment sample—Values are in parts per million

18. Au(1.13)
19. Au(0.16)
20. Au(0.30)
21. Au(0.30)

Quartz-vein sample—As(200 ppm)

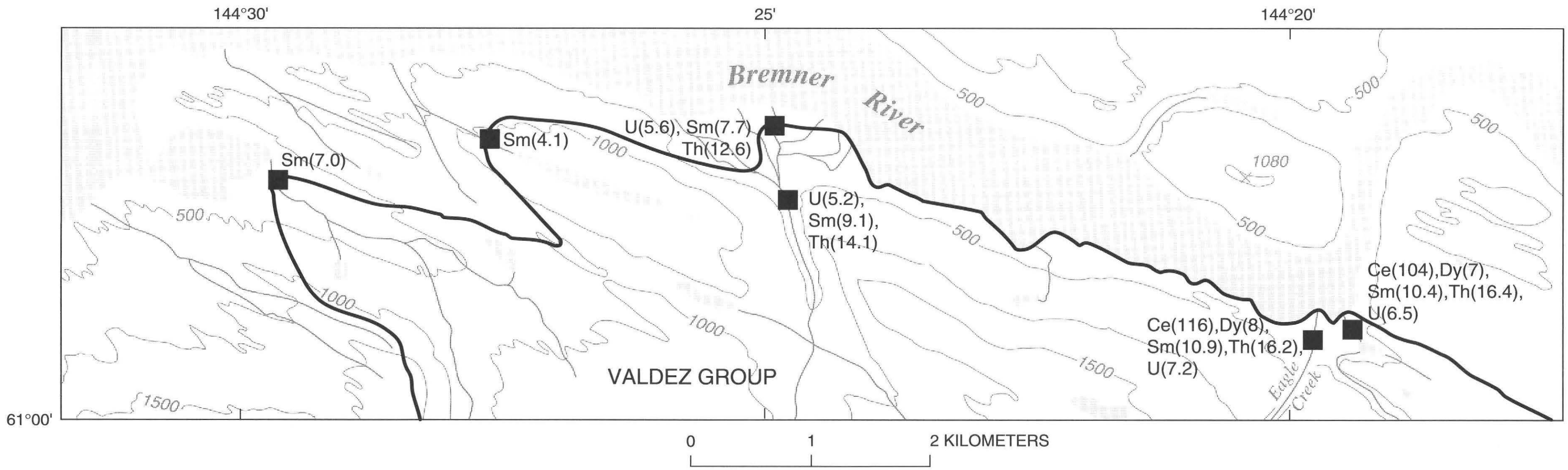
Placer gold prospect

Boundary of geochemically anomalous area

Mafic metavolcanic rock

Glacier

Figure 16. Geochemically anomalous stream-sediment, heavy-mineral-concentrate, and rock samples to the east of the Copper River and north of the Little Bremner River (geochemically anomalous area 9), Valdez 1°×3° quadrangle, Alaska. Area is underlain by metasedimentary rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.



EXPLANATION

■ **National Uranium Resource Evaluation sediment sample**—Values are in parts per million

—— **Boundary of geochemically anomalous area**

Figure 17. Geochemically anomalous stream-sediment samples south of the Bremner River (geochemically anomalous area 10), Valdez 1°×3° quadrangle, Alaska. Area is underlain by metasedimentary rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

AREA 11—EAST FORK OF THE BREMNER RIVER

Area 11 in the southeast corner of the Valdez quadrangle is entirely underlain by metasedimentary rocks of the Valdez Group (fig. 18). It is delineated by AMRAP concentrate samples containing 3–5 ppm Ag and 500–700 ppm Cu. Unlike many of the other areas underlain by rocks of the Valdez Group that contain anomalous silver, the concentrates from area 11 containing anomalous silver do not contain anomalous amounts of gold; one sample contains 0.3 ppm Au, and the other three contain less than 0.05 ppm Au. Concentrates from area 11 contain 20 percent Fe, but this might not be too significant because all of the southeast part of the study area is characterized by concentrate samples containing anomalous iron. Concentrations of as much as 700 ppm Pb and 340 ppm Zn in the samples from area 11 indicate, however, possible base-metal enrichments within the area. Values for manganese of 3,000–5,000 ppm and greater for concentrate samples from area 11 and from immediately to the south and east of the area indicate that the unknown source for manganese described in area 9 continues to the eastern edge of the Valdez quadrangle. High factor analysis scores onto factors 2 and 4 for samples from the area reflect the iron and manganese anomalies in the concentrate samples.

AMRAP stream-sediment samples lack anomalous silver values; however, at three of the sites containing anomalous silver in concentrate samples, corresponding stream-sediment samples contain 0.05–0.1 ppm Au. These data suggest that precious-metal-bearing veins might be the source for the anomalies in area 11. The lack of anomalous gold in concentrates from the area is puzzling. One possibility is that the gold grains being eroded in area 11 are finer than those sampled elsewhere in drainages underlain by rocks of the Valdez Group and therefore were lost during the panning process.

AREA 12—EAST OF TEBAY LAKES

AMRAP heavy-mineral-concentrate samples collected east of Tebay Lakes (area 12) suggest another area favorable for the presence of precious-metal-bearing quartz veins (fig. 19). The area is almost entirely underlain by metasedimentary rocks of the Valdez Group and extends just to the north of the Border Ranges fault. Two samples contain anomalous amounts of gold, two nearby samples contain high background values of 0.3 ppm Au, and one nearby sample contains anomalous amounts of silver. The sample collected a few hundred meters north of the toe of two large glaciers and 2 km southeast of peak 6439 contains 18 ppm Au. Element concentrations for corresponding sediment samples from area 12 are all at background levels.

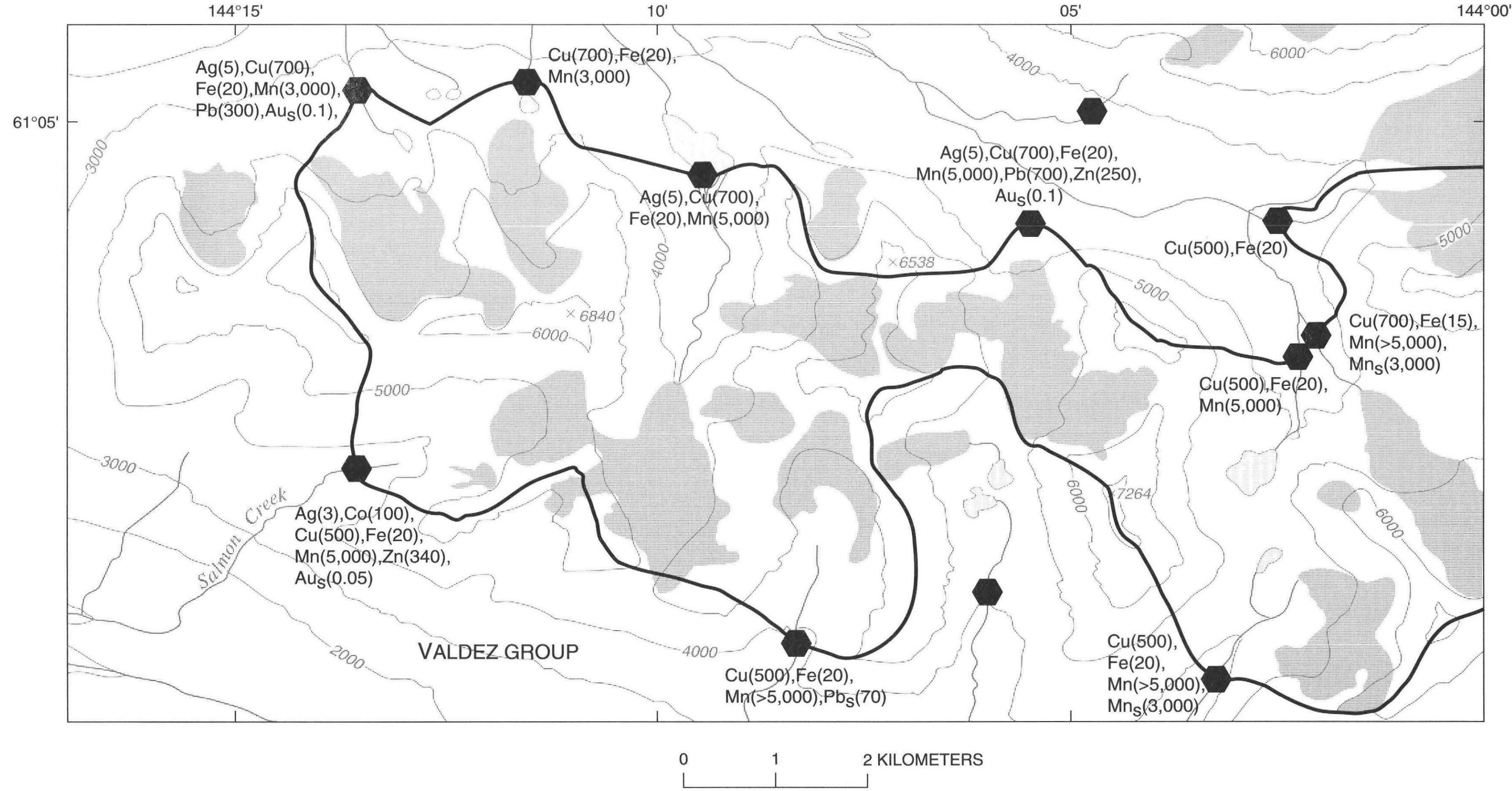
AREA 13—TONSINA MINING DISTRICT

Gold-bearing quartz veins from the Quartz Creek prospect in the Tonsina district (fig. 20*A*) contained as much as 1 ppm Au, 20 ppm Ag, >10,000 ppm As, and 10,000 ppm Pb (Miller and others, 1982). Surprisingly though, very few anomalies (figs. 20*A–E*) were found in sediment or concentrate samples collected in the Tonsina district. This lack of anomalous values may reflect either the presence of very fine grained gold in the source lodes or a relatively small surficial exposure of gold-bearing quartz veins. Four small areas in the Tonsina district were identified from anomalous amounts of silver, arsenic, or gold in AMRAP sediment or concentrate samples. Three of these (areas 13a, 13b, 13d) are almost exclusively underlain by metasedimentary rocks of the Valdez Group, and the fourth (area 13c) is underlain by rocks of the McHugh Complex. It is uncertain whether these anomalies reflect watersheds having greater favorability for gold-bearing veins as compared to other watersheds in the district, in which samples contain only background amounts of gold. A fifth small area in the Tonsina district (13e), also underlain by metasedimentary rocks of the Valdez Group, is defined by a NURE sediment sample containing 0.22 ppm Au. This sample, collected between two small lakes, probably reflects eroded material from the Eagle mine (Moffit, 1935).

Very few other anomalous values characterize samples from the Tonsina district. One exception is that many of the stream-sediments throughout the area contain 70–100 ppm Pb and elevated values for other felsic elements and are, therefore, characterized by high scores onto factor 2. The lack of corresponding concentrate anomalies suggests, however, a high background concentration in the sediments rather than the presence of galena grains. A concentrate sample on the western side of area 13d, collected downstream from an outcrop of mafic metavolcanic rocks of the Valdez Group, contains 700 ppm Cu. Winkler, Miller, and others (1981) described sulfide-bearing quartz veins and disseminated sulfides in mafic metavolcanic rocks near the toe of Tsina Glacier. Similar occurrences may be present in the southwest corner of area 13d and could be responsible for the anomalous copper value.

AREA 14—TIEKEL RIVER–STUART CREEK

A large area underlain by rocks of the Valdez Group, from lower Dewey Creek northwest to Greyling Creek, is defined by NURE stream-sediment samples that contain anomalous amounts of uranium (fig. 21). One sediment sample collected on the north side of the Tiekel River contains 21.5 ppm U, the highest uranium value from the NURE survey. Two sediment samples collected in the northwest corner of area 14 also are highly enriched in uranium, containing 11.8 and 14.2 ppm. To the south of area 14, a few



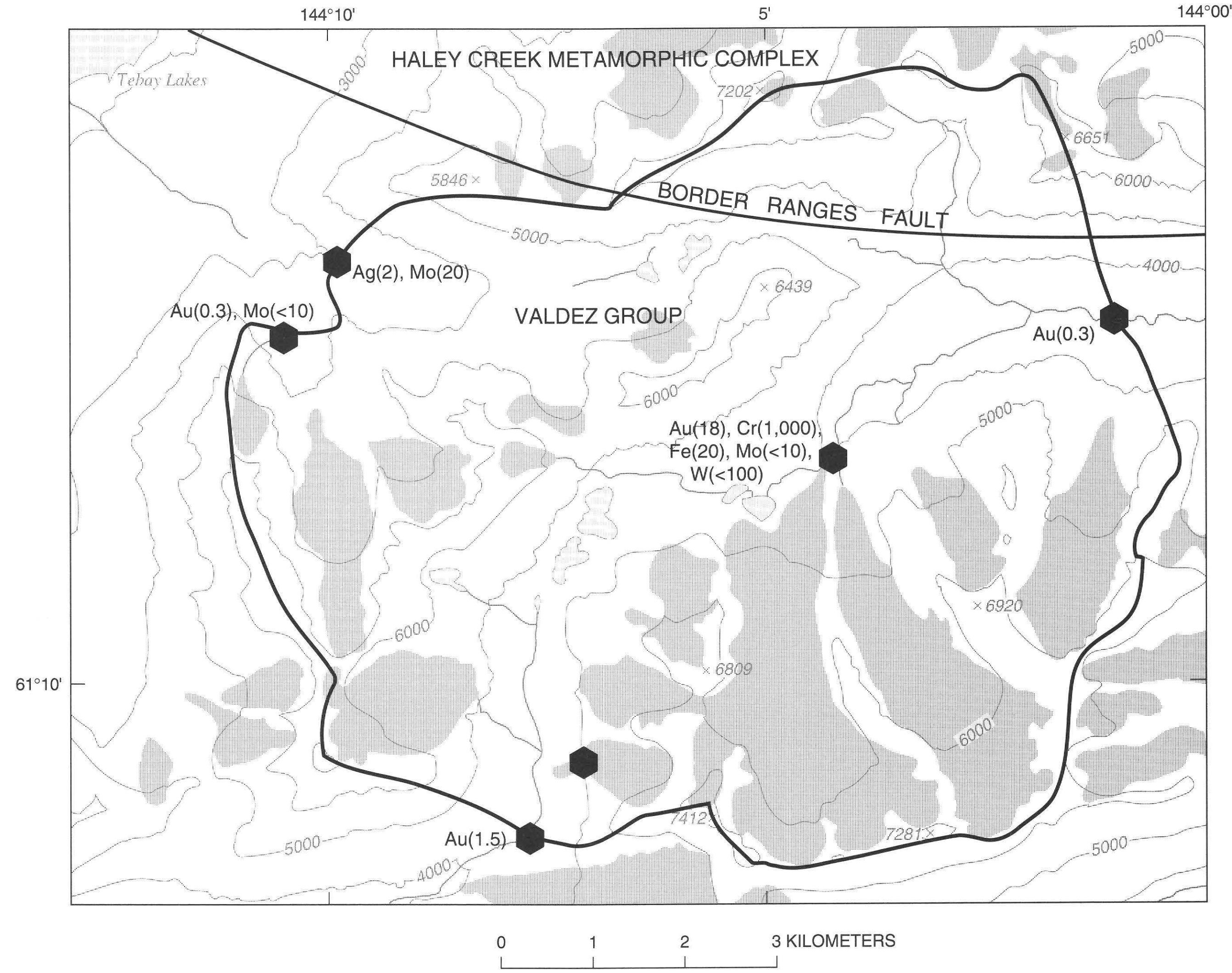
EXPLANATION

Alaska Mineral Resource Assessment Program sample—Values are in parts per million. Values are for concentrate samples except those accompanied by subscript "s," which are for sediment samples

Boundary of geochemically anomalous area

Glacier

Figure 18. Geochemically anomalous stream-sediment and heavy-mineral-concentrate samples within the tributaries of the East Fork of the Bremner River (geochemically anomalous area 11), Valdez 1°×3° quadrangle, Alaska. Area is underlain by metasedimentary rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.



EXPLANATION

Alaska Mineral Resource Assessment Program concentrate sample—Values are in parts per million

Boundary of geochemically anomalous area

Fault—Approximately located

Glacier

Figure 19. Geochemically anomalous heavy-mineral-concentrate samples to the east of Tebay Lakes (geochemically anomalous area 12), Valdez 1°×3° quadrangle, Alaska. Area south of the Border Ranges fault is underlain by metasedimentary rocks of the Valdez Group; area north of fault is underlain by rocks of the Haley Creek metamorphic assemblage of the Wrangellia terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

samples anomalous in uranium hint at an extension of the anomalous zone south to Cleave Creek. Many of the NURE samples in area 14 that contain anomalous uranium also have high background or anomalous values for lead. NURE water samples at the sites that have 21.5 and 11.8 ppm U in stream sediments, contain 3.97 and 8.89 ppb U, respectively. In addition, many of the sediment samples from the AMRAP survey in the western part of area 14 are also anomalous in lead. Uranium-enriched silicate minerals in the widespread felsic dikes intruding the metasedimentary rocks in this part of the Chugach terrane are the most likely source for the anomalies.

AREA 15—ERNESTINE CREEK

The Ernestine Creek area is delineated by eight AMRAP sediment samples containing 0.1–0.7 ppm Au, two concentrate samples containing 1.25 and 5 ppm Au, and a third concentrate sample containing 2 ppm Ag (fig. 22). The area is almost entirely underlain by metasedimentary rocks of the Valdez Group. A few small outcrops of mafic metavolcanic rocks also are present. Placer gold was prospected for on Ernestine Creek (Rohn, 1900), immediately north of the boundary of area 15, and on Fall Creek, about 3 km west of the boundary.

The anomalies in area 15 likely reflect precious-metal-bearing quartz veins in rocks of the Valdez Group. The more consistent gold anomalies in stream-sediment samples rather than heavy-mineral-concentrate samples, in contrast to many of the other anomalous areas underlain by rocks of the Valdez Group, suggest that fine-grained gold may be lost during concentration procedures. The two most anomalous AMRAP sediment samples, each containing 0.7 ppm Au, were collected north of the toe of the glacier at the head of Ernestine Creek and at the toe of the glacier about 3 km northwest of peak 5593. A NURE stream-sediment sample collected at the latter site also contains 0.78 ppm Au. Base metals are generally at background levels in all samples. The one exception is a concentrate collected below the valley draining peak 5806 in the southeast corner of area 15. The sample contains anomalous amounts of Fe, Mn, Cu, Pb, W, and Zn.

AREA 16—MT. OURAND

Metasedimentary rocks of the Valdez Group in the vicinity of Mt. Ourand are favorable hosts for base- and precious-metal-bearing quartz veins. One sediment sample collected from the northwest corner of area 16 contains 0.1 ppm Au (fig. 23). At two other sites, heavy-mineral-concentrate samples contain anomalous amounts of silver, iron, cobalt, copper, molybdenum, lead, or zinc. One of the corresponding sediment samples also contains anomalous amounts of copper, lead, and zinc.

AREA 17—NORTH OF TONSINA GLACIER

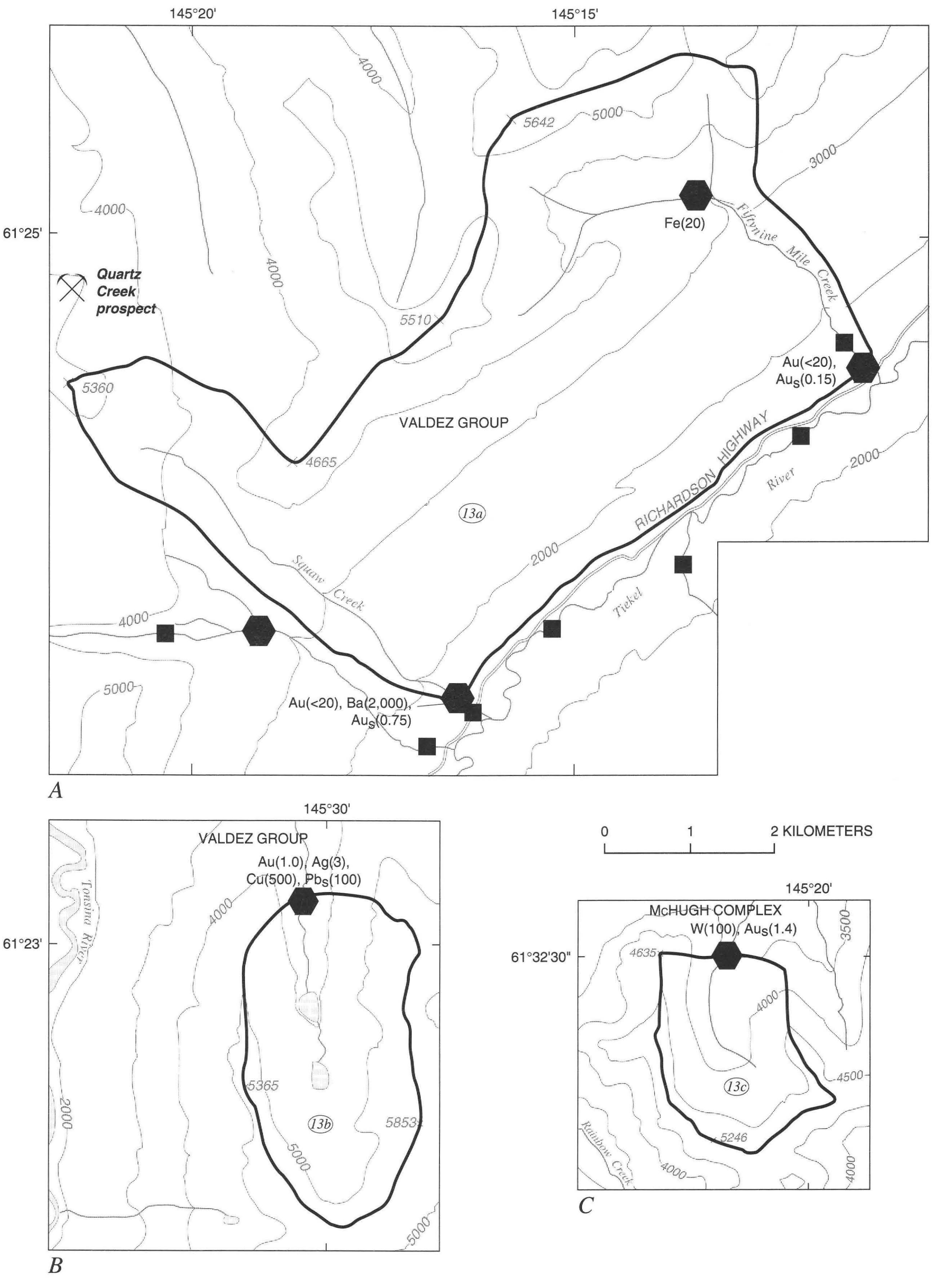
A single concentrate sample collected at the toe of a small glacier north of Tonsina Glacier contains 1.9 ppm Au (fig. 24). The source of the anomaly is probably gold-bearing quartz veins within metasedimentary rocks of the Valdez Group. No other anomalies or mineral occurrences are known from the area.

AREA 18—BLACK MOUNTAIN

The region east of Black Mountain is delineated by 12 anomalous heavy-mineral-concentrate samples (fig. 25). The area is underlain mostly by metasedimentary rocks of the Valdez Group and minor intercalated mafic metavolcanic rocks. Felsic dikes are abundant in the northern part of the area. High scores onto factor 2 for stream-sediment samples reflect the felsic rocks. AMRAP concentrate samples are anomalous in Fe, Mn, Ag, As, Au, B, Be, Co, Cu, Mo, Ni, Pb, W, or Zn and have high factor 2 scores. Samples downstream from peak 5767 and northeast of Bence Mountain have large suites of anomalous elements and hint at localities most favorable for base-metal mineral occurrences. A NURE stream-sediment sample also downstream from peak 5767 contains 243 ppm Zn. A value of 1,000 ppm Zn for a concentrate sample collected in the headwaters of Greyling Creek is the highest such value from the AMRAP survey. The corresponding stream-sediment contains 180 ppm Zn, and a NURE sediment sample from the same general location contains 177 ppm Zn. Therefore, the southeast corner of area 18 also has potential for base-metal-bearing mineral occurrences.

A number of samples having precious-metal anomalies also are present in area 18. A concentrate sample collected from near the headwaters of Manker Creek contains 2.5 ppm Au. A concentrate from a creek north of peak 6040 contains 10 ppm Ag and 3,000 ppm Cu. The two stream channels in the southwestern part of area 18 yield concentrate samples that contain anomalous amounts of arsenic and iron. One of these samples also contains 7 ppm Ag and anomalous amounts of boron, cobalt, copper, and tungsten. Two concentrate samples collected on the northeast side of Bence Mountain contain 200 and 500 ppm W, the highest values from the AMRAP survey. The anomalous tungsten may be associated with gold-bearing veins because scheelite is a common accessory mineral in such deposits where hosted by igneous rocks. A stream-sediment collected at the same site as one of the tungsten-rich concentrate samples contains 0.1 ppm Au, 200 ppm Cu, and 100 ppm Pb.

These anomalous gold, silver, and arsenic values are likely indicative of upstream precious-metal-bearing quartz veins. The felsic igneous dikes mapped within and immediately to the east of area 18 (Winkler, Silberman, and others, 1981) might be hosts for such veining. In the Hope-Sunrise district (near Anchorage), also mostly underlain by metasedimentary rocks of the Valdez Group, many of the gold-, pyrite-, and arsenopyrite-bearing quartz veins are spatially associated with felsic dikes (Tuck, 1933). Such an association may reflect migration of dike-forming melts and later vein-forming fluids along the same conduits, as well as preferential fracturing of the more competent igneous rock.


145°20'
145°15'
61°25'
Quartz Creek prospect
4000
5642
5000
3000
Fe(20)
Fiftynine Mile Creek
5510
5360
Au(<20), Aus(0.15)
VALDEZ GROUP
4665
RICHARDSON HIGHWAY
River
2000
13a
Squaw Creek
Tiekel
Au(<20), Ba(2,000), Aus(0.75)
A
145°30'
VALDEZ GROUP
Au(1.0), Ag(3), Cu(500), Pbs(100)
61°23'
Tonsina River
5365
13b
5853
B
0 1 2 KILOMETERS
145°20'
McHUGH COMPLEX
W(100), Aus(1.4)
61°32'30"
4635
3500
4500
13c
5246
Rainbow Creek
C

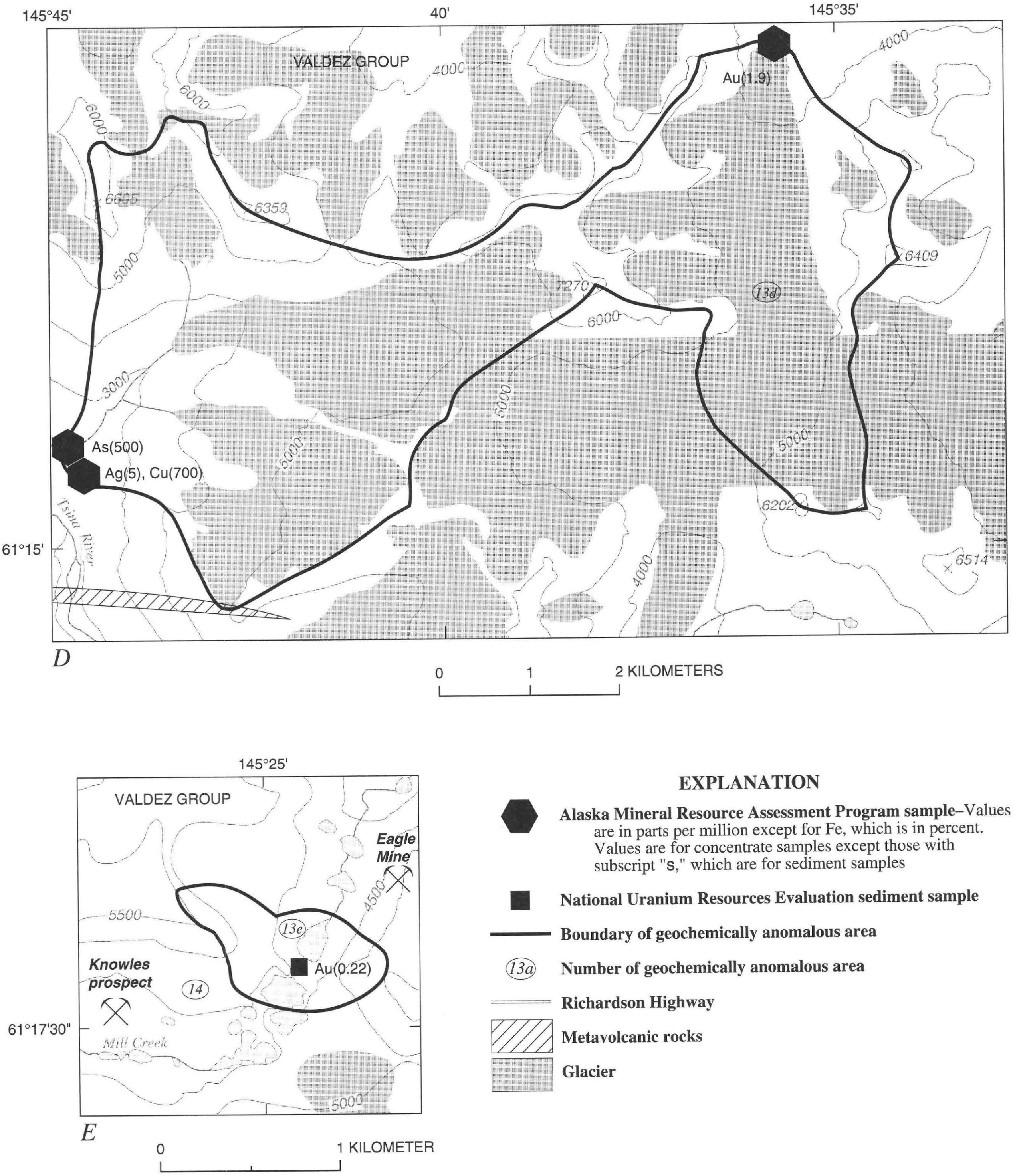
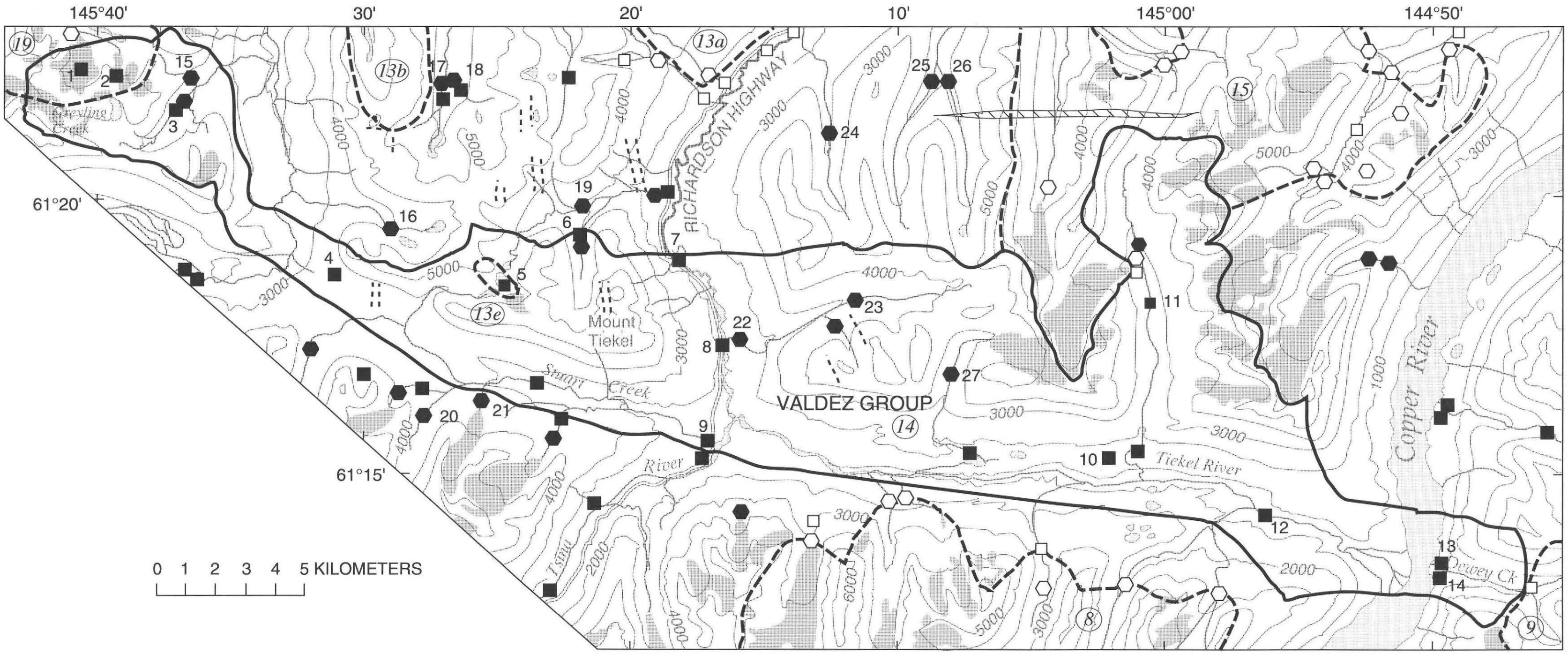


Figure 20 (above and facing page). Geochemically anomalous stream-sediment and heavy-mineral-concentrate samples in the Tonsina mining district including Fiftynine Mile and Squaw Creeks (geochemically anomalous area 13a), just east of the Tonsina River (geochemically anomalous area 13b), east of Rainbow Creek (geochemically anomalous area 13c), east of the Tsina River (geochemically anomalous area 13d), and near the headwaters of Mill Creek (geochemically anomalous area 13e), Valdez 1°×3° quadrangle, Alaska. Areas 13a, 13b, 13d, and 13e are underlain by metasedimentary rocks and rarely metavolcanic rocks of the Valdez Group of the Chugach terrane; area 13c is underlain by rocks of the McHugh Complex of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000; contour interval 1,000 ft for areas 13a, 13b, and 13d and 500 ft for areas 13c and 13e.



EXPLANATION

■ **National Uranium Resource Evaluation sample**—Sediment-sample values are in parts per million; water-sample values are in parts per billion. Values are for stream-sediment samples except those accompanied by subscript "w," which are for stream-water samples

1. Pb(23), U(14.2)
2. Co(34.4), Ni(82), Pb(23), U(11.8), U_w(8.89)
3. Bi(6), U(4.0)
4. U(12.8)
5. Au(0.22), U(5.1)
6. U(4.2)
7. Pb(16), U(4.3)
8. Pb(67), U(7.9), Zn(197)
9. U(10.4)
10. U(21.5), U_w(3.97)
11. U(4.2)
12. U(10.0)
13. U(4.1)
14. Au(0.78)

⬢ **Alaska Mineral Resource Assessment Program sample**—Values are in parts per million. Values are for sediment samples except those accompanied by subscript "c," which are for concentrate samples

15. Cu(200), Pb(100)
16. Pb(70)
17. Pb(70)
18. Pb(70), Zn(190), Ba_c(2,000)
19. Fe_c(20), W_c(200)
20. Pb(70)
21. Mo_c(<10)
22. Au_c(<200)
23. Pb(70)
24. Au(0.05), Fe_c(20)
25. Cu_c(500)
26. Au(0.05), Cu_c(500)
27. Au_c(0.8)

□⬡ **Samples discussed in sections describing other geochemically anomalous areas**

—— **Boundary of geochemically anomalous area**

– – – **Boundary of adjacent geochemically anomalous area**

(14) **Number of geochemically anomalous area**

Richardson Highway

Felsic dike

Metavolcanic rocks

Glacier

Figure 21. Geochemically anomalous stream-sediment, heavy-mineral-concentrate, and stream-water samples within and adjacent to the Tiekel River and Stuart Creek watersheds (geochemically anomalous area 14), Valdez 1°×3° quadrangle, Alaska. Area is underlain by rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

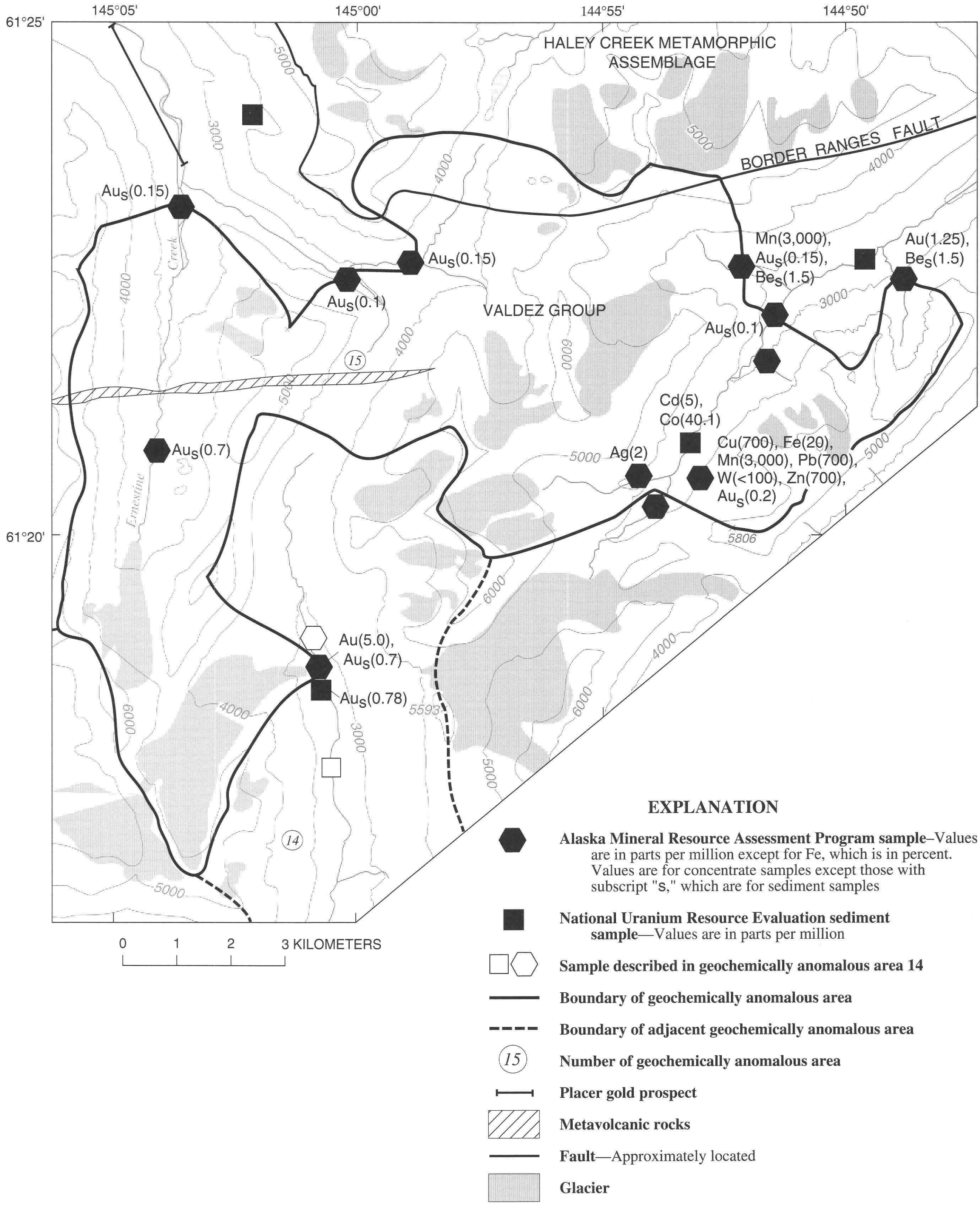
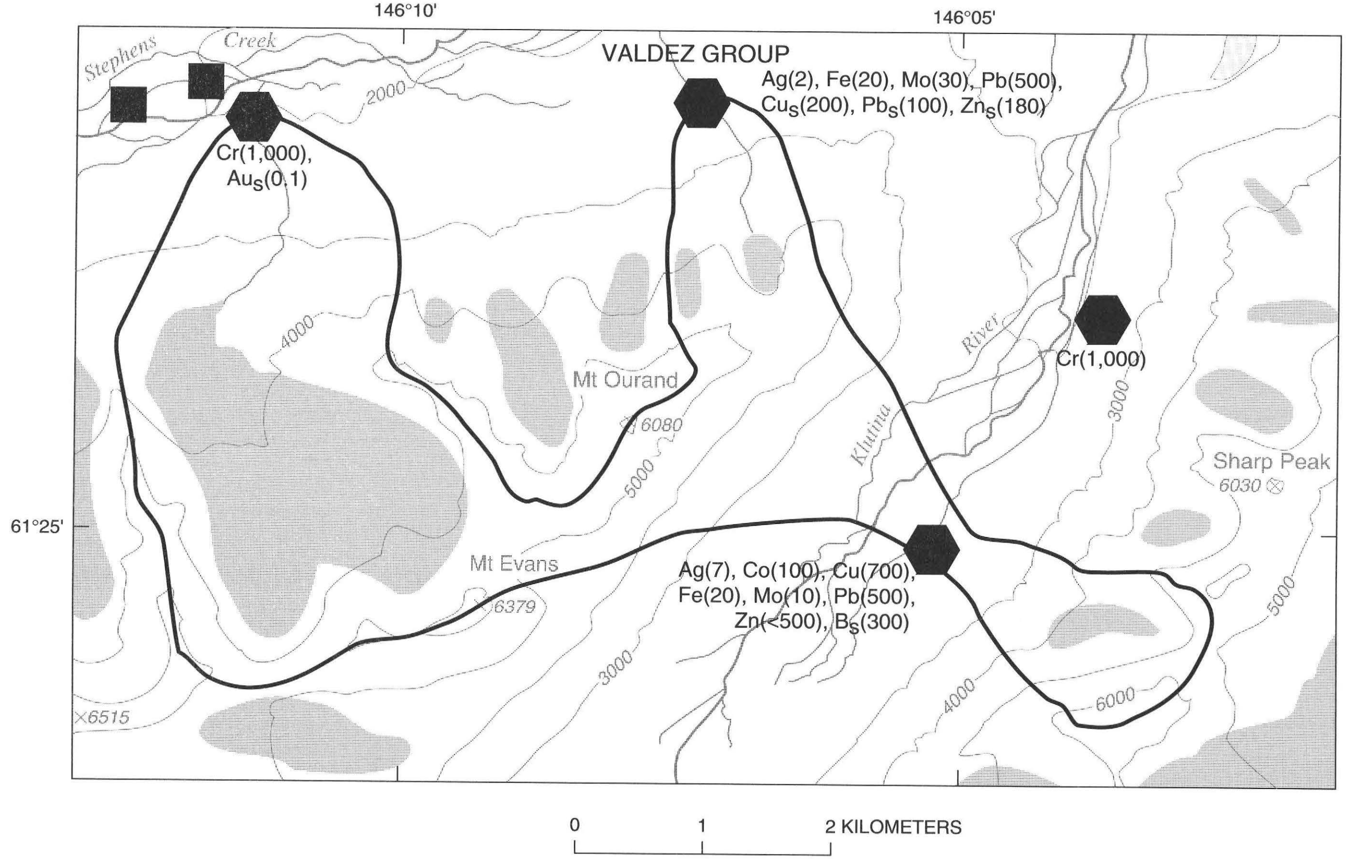


Figure 22. Geochemically anomalous stream-sediment and heavy-mineral-concentrate samples along and to the east of Ernestine Creek (geochemically anomalous area 15), Valdez 1°×3° quadrangle, Alaska. Area south of the Border Ranges fault is underlain by rocks of the Valdez Group of the Chugach terrane; area north of the fault is underlain by rocks of the Haley Creek metamorphic assemblage of the Wrangellia terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.



EXPLANATION

Alaska Mineral Resource Assessment Program sample—Values are in parts per million except for Fe, which is in percent. Values are for concentrate samples except those accompanied by subscript "S," which are for sediment samples

National Uranium Resource Evaluation sediment sample

Boundary of geochemically anomalous area

Glacier

Figure 23. Geochemically anomalous stream-sediment and heavy-mineral-concentrate samples in the vicinity of Mt. Ourand (geochemically anomalous area 16), Valdez 1°×3° quadrangle, Alaska. Area is underlain by metasedimentary rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

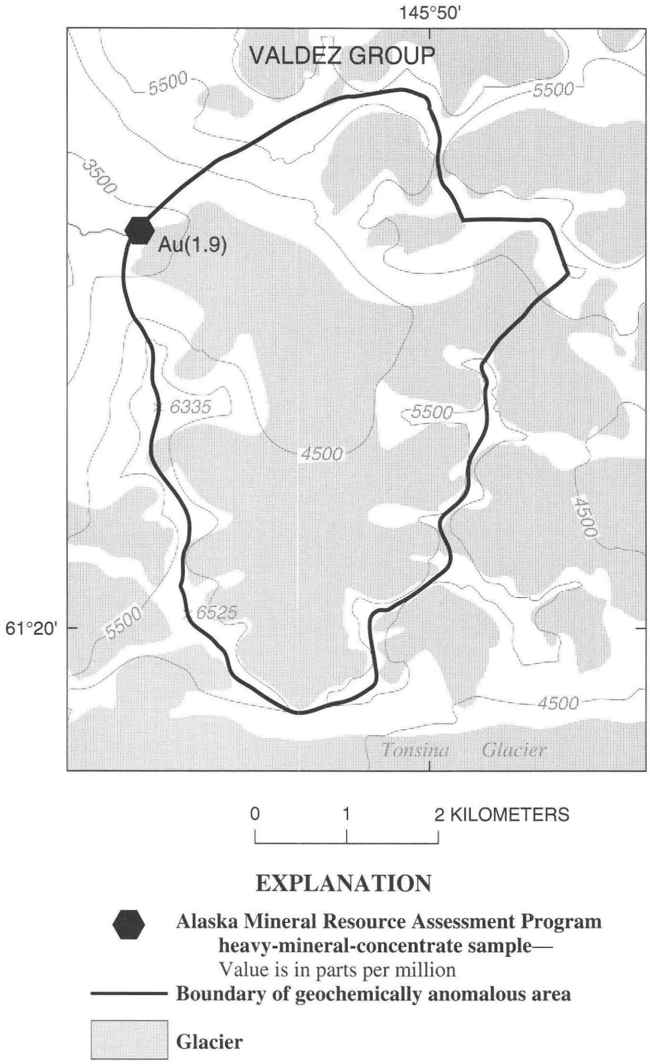


Figure 24. Location of a heavy-mineral-concentrate sample containing 1.9 ppm gold to the north of Tonsina Glacier (geochemically anomalous area 17), Valdez 1°×3° quadrangle, Alaska. Area is underlain by metasedimentary rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

AREA 19—GREYLING LAKE

Stream-sediment samples east of Greyling Lake are anomalous in zinc (fig. 26). Metasedimentary rocks of the Valdez Group underlie most of the area, and felsic dikes crop out in a few locations. Four AMRAP stream-sediment samples from the area contain 170–240 ppm Zn. The value of 240 ppm, from a sample collected between two ponds southeast of peak 6235, is the highest zinc value from stream-sediment samples analyzed in the AMRAP survey. The anomalous sediment samples also contain 1.5–2 ppm Be and 70–100 ppm Pb. High positive scores for the sediment samples onto both factor 2 (dominated by Ba, Zr, Pb, Y, Be, Zn, and B) and factor 3 (dominated by Cu and Zn) reflect felsic igneous rock and base-metal sulfide contributions, respectively. Two NURE sediment samples collected from the south end of area 19 contain 23 ppm Pb, 11.8 and 14.2 ppm U, and anomalous amounts of many rare earth elements. Area 19, similar to area 18 on the opposite side of Greyling Creek, is geochemically favorable for base-metal-bearing mineral occurrences.

AREA 20—KIMBALL PASS

Area 20 is mostly along the ridge to the southeast and east of Kimball Pass (fig. 27). (Area 20a is in the headwaters of Dust, Liberty, and O'Brien Creeks; area 20b is in the headwaters of Bernard Creek.) It is defined by five AMRAP stream-sediment samples that contain 0.05–0.95 ppm Au and a NURE stream-sediment sample that contains 0.62 ppm Au. The area is underlain by highly deformed and juxtaposed sequences of metasedimentary rocks of the Valdez Group, melange of the McHugh Complex, and unnamed metasedimentary, metavolcanic, and metaplutonic rocks of the southern Wrangellia terrane margin (Plafker, Lull, and others, 1989). Four gold-bearing quartz vein prospects are within 5 km of the northwest edge of area 20b near Kimball Pass, and gold-bearing quartz veins of the Opal and related mines are 5 km to the east of area 20a (MacKevett and Holloway, 1977; Winkler, Miller, and others, 1981). Similar vein occurrences are likely to be present in area 20.

Three NURE stream-sediment samples from area 20a are anomalous in zinc. One of these, collected from the headwaters of O'Brien Creek, contains 443 ppm Zn, 1,235 ppm Ba, 271 ppm Co, 18.6 ppm Cs, 5.1 ppm Eu, 33 percent Fe, and 98 ppm Sc. These are the highest concentrations for all these elements from the NURE survey. Uranium, chromium, and rubidium are also anomalous in the sample. Although not delineated in figure 27, there is a strong likelihood that the zinc anomalies in area 20a extend another 8 km to the north. Three NURE sediment samples from the north side of the mountain between Liberty Falls and the benchmark "Scarp" (pl. 1) contain 227–256 ppm Zn. The source for the anomalous zinc is uncertain; however, Miller and others (1982) indicated that schist only 3 km south of area 20, in the headwaters of the Uranatina River, contains 700 ppm Zn, 500 ppm B, and 70 ppm Mo. Visible sphalerite grains were noted in some of the sampled schist.

The lowest pH values in stream-water samples collected during the NURE survey cluster both within and downstream of area 20b. The three lowest pH measurements from the survey, between 3.6 and 3.8, are in the headwaters of Bernard Creek. These low pH values might indicate the presence of abundant sulfide minerals within the upper basin of Bernard Creek; however, the generally low iron, cobalt, and nickel values for heavy-mineral-concentrate samples from the same area are not consistent with an abundance of pyrite.

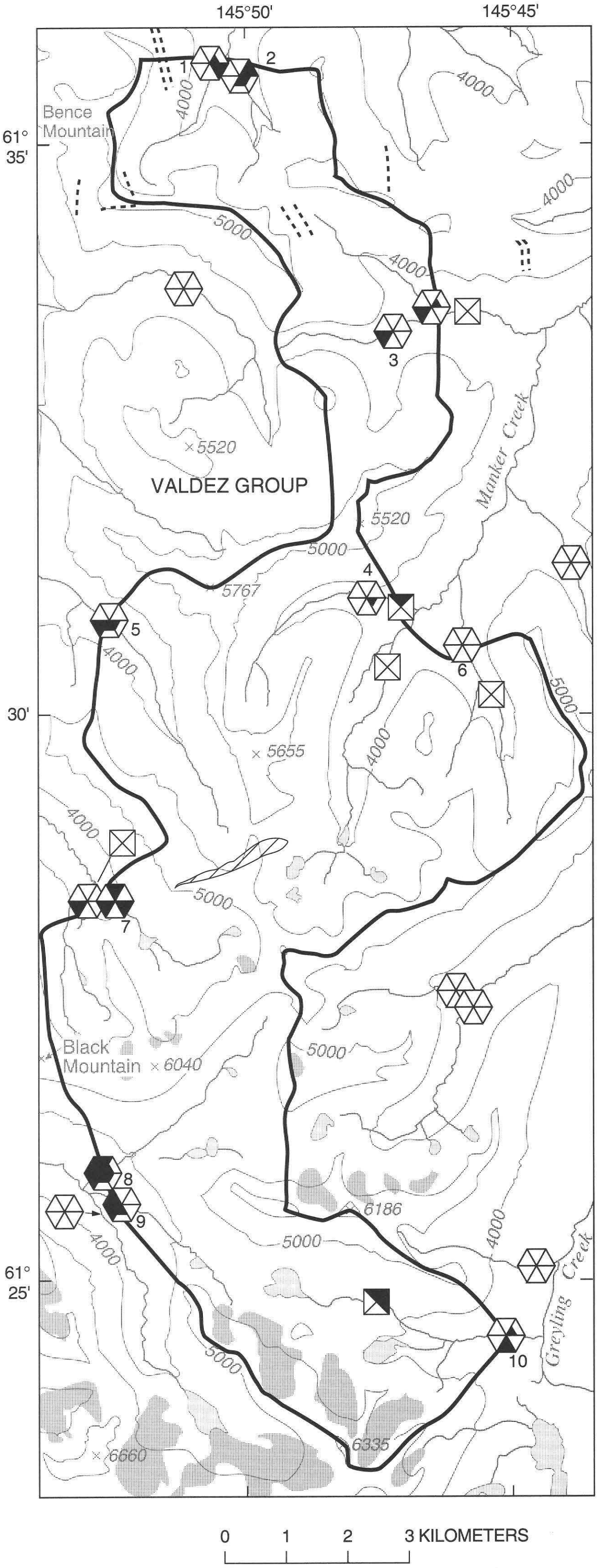
AREA 21—BERNARD AND DUST CREEKS

A large area between Liberty Creek and the Richardson Highway is predominantly defined by sediment samples that have anomalous chromium values (fig. 28) and anomalous factor analysis scores onto sediment factor 1. Four sediment samples from the AMRAP survey and nine from the NURE survey are anomalous in chromium. Chromium values range from 1,000 to 5,000 ppm in the AMRAP samples, and the samples also contain as much as 15 percent Fe, 7 percent Mg, 1,000 ppm Ni, and 700 ppm V. Corresponding heavy-mineral-concentrate samples were not collected at any of the sites. The most anomalous NURE sediment sample, collected along Dust Creek, contains 1,074 ppm Cr. Most of the NURE sediments are also anomalous in nickel.

Chromite lenses and disseminations within the Border Ranges ultramafic-mafic assemblage are the likely source for the anomalous chromium in stream sediments. Area 21 contains known chromite occurrences at Bernard and Dust Mountains. At Bernard Mountain, ultramafic rocks contain as much as 15 percent Fe, >10 percent Mg, >5,000 ppm Cr, and 2,000 ppm Ni (Miller and others, 1982). Talc schist from area 21 (rock sample F, fig. 28) contains 150 ppm Co, >5,000 ppm Cr, and 1,500 ppm Ni. Ultramafic rocks from the "Scarp" benchmark at the northeast corner of the area contain as much as 15 percent Fe, >10 percent Mg, 15 percent Ca, 200 ppm Co, >5,000 ppm Cr, 1,000 ppm Ni, and 1,000 ppm Cu (Miller and others, 1982). Although no chromite prospects are known from the eastern side of area 21, a sample of ultra-mafic rock from near peak 5990 (rock sample K, fig. 28) contains 10 percent Mg, 2,000 ppm Cr, and 1,000 ppm Ni (Miller and others, 1982).

Sutley and others (1990) conducted part of a geochemical pilot study in the vicinity of the Bernard Mountain occurrence. They indicated that chromium is the only element in analyzed stream sediments and heavy-mineral-concentrate samples that can distinguish upstream chromite occurrences from high lithogeochemical backgrounds for the Border Ranges ultramafic-mafic assemblage. Therefore, within area 21, stream-sediment samples having highest chromium concentrations are obviously the best pathfinders for upstream mineral occurrences.

Newberry (1986) described metagabbronorite and garnet granulite containing 2–6 percent sulfide minerals



EXPLANATION

Ag / As W / Mo Cu / Zn

Alaska Mineral Resource Assessment Program sample—Values are in parts per million except Fe, which is in percent. Values are for concentrate samples except those accompanied by subscript "s," which are for sediment samples. Leaders (--), no value for that category

Category	Map symbol	Ag	W	Cu	Zn	Mo	As
Anomalous	▼	--	100–200	500–700	<500–700	--	--
Highly anomalous	▼	7–10	500	1,500–3,000	1,000	<1–20	(<500–700)

Additional anomalous values: 1, Au_s(0.1), Cu_s(200), Pb_s(100); 2, Co(100), Cu_s(200); 3, Co(150), Fe(20), Mn(5,000), Ni(300); 4, Co(100), Fe(20), Mn(5,000); 5, Co(100), Mn(3,000), Pb(300), B_s(300), Be_s(1.5); 6, Au(2.5), Be_s(2.0), Pb_s(70), Zn_s(200); 7, Co(100), Fe(20); 8, B(700), Co(100), Fe(20), Be_s(2); 9, Be(3), Fe(20), Be_s(2); 10, Be_s(2), Zn_s(180)

Zn / Ni Co

National Uranium Resource Evaluation sediment sample—Values are in parts per million

Category	Map symbol	Zn	Co	Ni
Anomalous	▼	177–243	33.2	84

Boundary of geochemically anomalous area

Metavolcanic rocks

Felsic dike swarm

Glaciers

Figure 25 (above and facing column). Geochemically anomalous stream-sediment and heavy-mineral-concentrate samples between Greyling Creek and Bence Mountain (geochemically anomalous area 18) (Black Mountain), Valdez 1°×3° quadrangle, Alaska. Area is underlain by metasedimentary rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

from an outcrop about 1 km northwest of the benchmark "Scarp." Pyrite is the predominant sulfide, and minor amounts of marcasite and chalcopyrite are present. Such magmatic sulfide occurrences may be responsible for some of the stream-sediment anomalies that define area 21.

AREA 22—SUMMIT LAKE

The area near Summit Lake is characterized by stream-sediment samples generally anomalous in cobalt and copper (fig. 29). The samples also have anomalous scores for factor 1, dominated by the mafic elements. The area is cut by the Tebay fault and a number of other high-angle faults. North of the Tebay and Canyon Creek faults are mostly greenstone and marine sedimentary rocks of the Skolai Group within the Wrangellia terrane (Winkler Silberman, and others, 1981). Disseminated and massive copper-sulfide-bearing occurrences are present at Surprise Creek, Divide Creek, and Falls Creek (Moffit, 1914; Winkler, Silberman, and others, 1981). South of the Tebay fault, magmatic copper and nickel occurrences at Spirit Mountain and near Summit Lake (Herreid, 1970; MacKevett and Holloway, 1977) are hosted by ultramafic sills within rocks of the Wrangellia terrane. The sills intrude complexly deformed metasedimentary and metaplutonic rocks. Sulfide bodies at Spirit Mountain contain as much as 20 percent Fe, 15 ppm Ag, 2,000 ppm Co, >20,000 ppm Cu, >5,000 ppm Ni, and 0.4 ppm Au. Associated quartz veins contain >10,000 ppm As, 3,000 ppm Cu, >5,000 ppm Ni, and 7.0 ppm Pd, and an ultramafic rock sample contains 50 ppb Pt (Miller and others, 1982).

Area 22 is mainly delineated by AMRAP stream-sediment samples that contain 100 ppm Co and 200–300 ppm Cu. Some sediment samples also contain 200 ppm Ni, 100 ppm Pb, and 700 ppm Cr. These anomalies identify watersheds most favorable for the occurrence of the copper and nickel sulfides. Alternatively, the lack of anomalous metal concentrations in corresponding heavy-mineral-concentrate samples may suggest that the sediment enrichments are due to the abundance of mafic rock types and not to sulfide mineral grains. The distribution of rocks of the Skolai Group and mafic sill-hosting units is much broader, however, than that in area 22 and therefore argues against a solely lithogeochemical background signature for the anomalies.

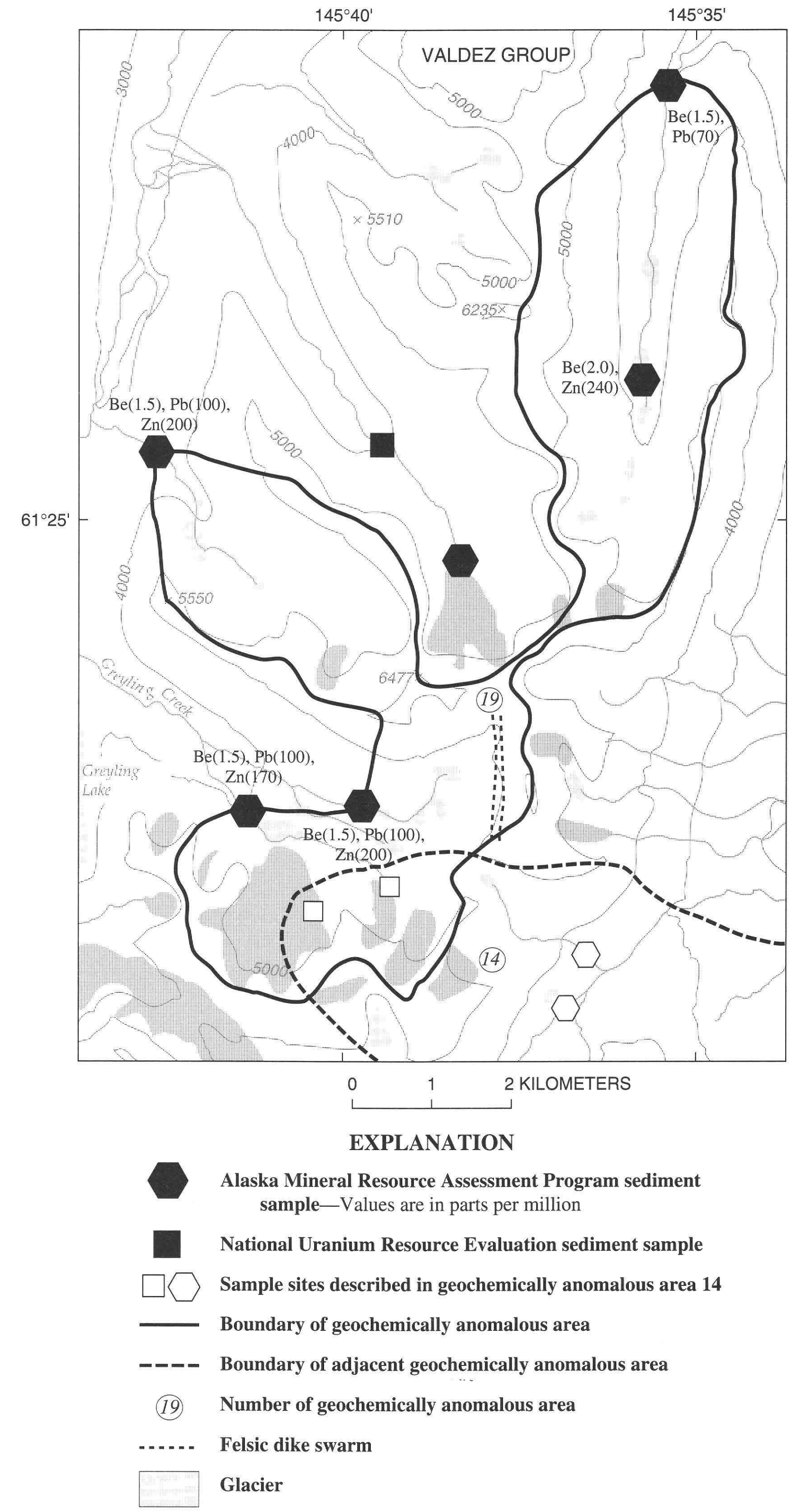
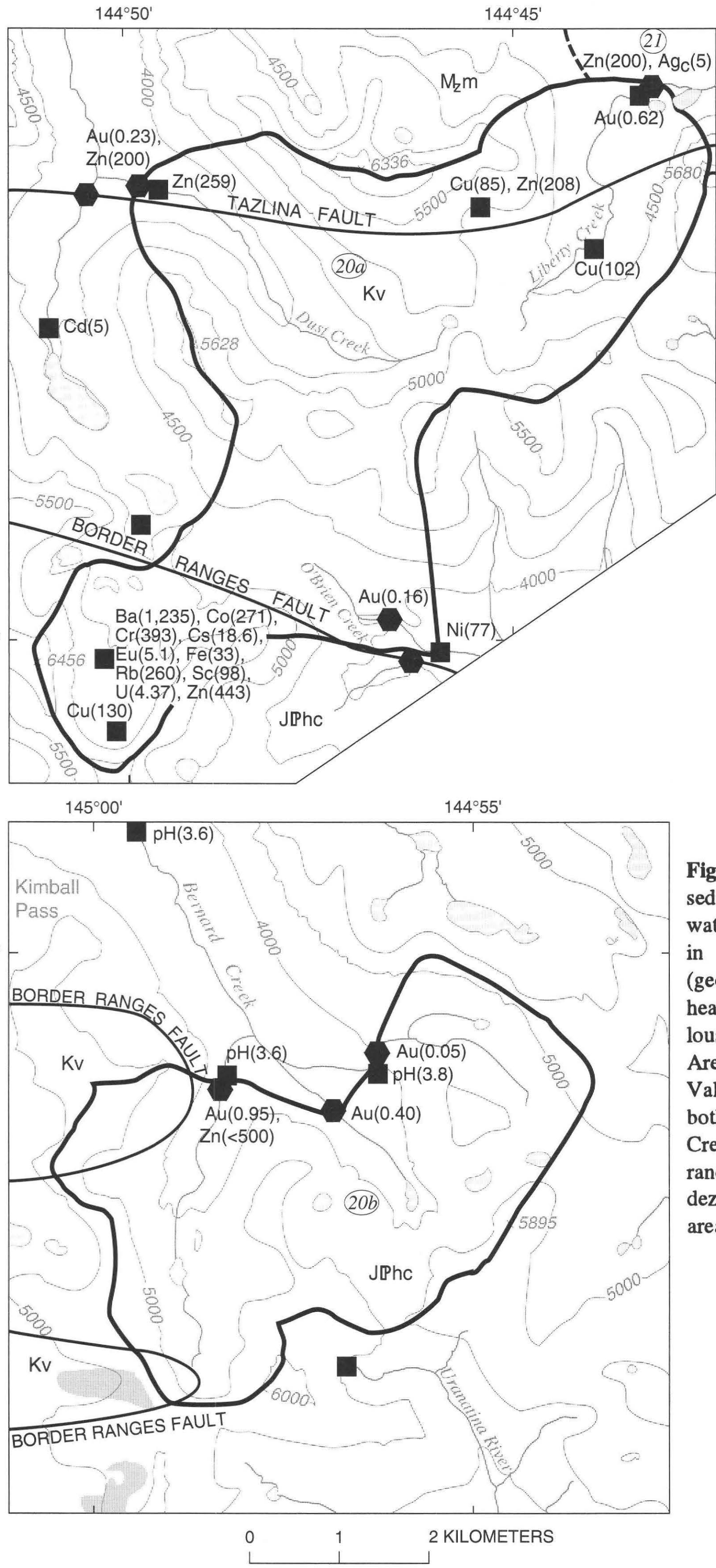


Figure 26. Geochemically anomalous stream-sediment samples to the east of Greyling Lake (geochemically anomalous area 19), Valdez 1°×3° quadrangle, Alaska. Area is underlain by metasedimentary rocks of the Valdez Group of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.



EXPLANATION

Alaska Mineral Resource Assessment Program sample—Values are in parts per million. Values are for sediment samples except that accompanied by subscript "c," which is for a concentrate sample

National Uranium Resource Evaluation sample site—Values are in parts per million except Fe, which is in percent. All data are for stream-sediment samples except for pH values, which are for stream-water samples

Boundary of geochemically anomalous area

Boundary of adjacent geochemically anomalous area

(20a) **Number of geochemically anomalous area**

Kv **Valdez Group (Late Cretaceous) of the Chugach terrane**

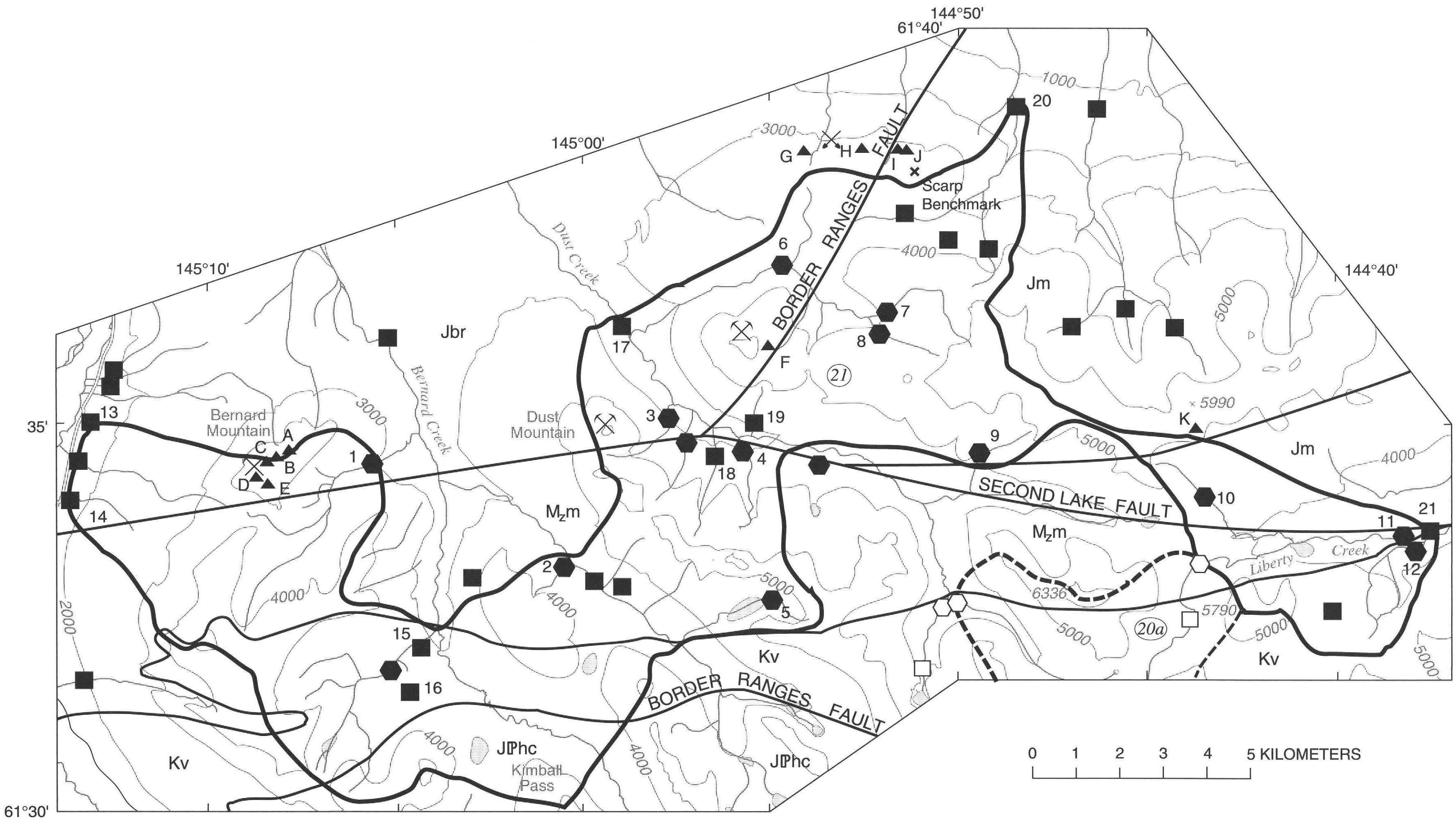
M$_z$m **McHugh Complex (Mesozoic) of the Chugach terrane**

JPhc **Haley Creek metamorphic assemblage (Late Jurassic and Pennsylvanian and older?) of the Wrangellia terrane**

Fault—Approximately located

Glacier

Figure 27. Geochemically anomalous stream-sediment, heavy-mineral-concentrate, and stream-water samples to the southwest of Kimball Pass, within the Liberty, Dust, and O'Brien Creeks area (geochemically anomalous area 20a) and within the headwaters of Bernard Creek (geochemically anomalous area 20b), Valdez 1°×3° quadrangle, Alaska. Area is underlain by metasedimentary rocks of the Valdez Group and melange of the McHugh Complex, both of the Chugach terrane, and rocks of the Haley Creek metamorphic assemblage of the Wrangellia terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000; contour interval 500 ft for area 20a and 1,000 ft for area 20b.


144°50'
61°40'
145°00'
145°10'
144°40'
35'
61°30'
BORDER RANGES FAULT
SECOND LAKE FAULT
Scarp Benchmark
Bernard Mountain
Dust Mountain
Kimball Pass
Dust Creek
Bernard Creek
Liberty Creek
Jbr
Jm
Mzm
Kv
JPhc
0 1 2 3 4 5 KILOMETERS

EXPLANATION

Alaska Mineral Resource Assessment Program stream-sediment sample—Values are in parts per million except Mg, which is in percent

1. Cr(3,000), Ni(300), V(700)
2. V(700)
3. Co(100), Cr(5,000), Mg(7), Ni(1,000)
4. Co(100), V(700)
5. Cu(200)
6. Cr(2,000)
7. V(700)
8. V(700)
9. V(700), Zn(200)
10. Cr(1,000), Ni(300), V(700)
11. Cu(200)
12. Cu(200)

Alaska Mineral Resource Assessment Program rock sample—Values are in parts per million except Fe and Mg, which are in percent

A. Cr(5,000), Mg(10)
B. Cr(>5,000), Fe(15), Mg(>10), Ni(1,500)
C. Cr(3,000), Fe(15), Mg(>10), Ni(2,000)
D. Cr(2,000), Mg(>10), Mn(2,000)
E. Cr(2,000), Mg(>10), Ni(2,000)
F. Co(150), Cr(>5,000), Ni(1,500)
G. Fe(15)
H. Co(200), Cu(800), Fe(15)
I. Cr(>5,000), Mg(>10), Ni(1,000)
J. Co(200), Cr(>5,000), Cu(1,000), Fe(15), Mg(>10), Ni(500)
K. Cr(2,000), Mg(10), Ni(1,000)

National Uranium Resource Evaluation sediment sample—Values are in parts per million

13. Cr(408), Ni(64)
14. Cr(229)
15. Bi(5)
16. Cr(193)
17. Cr(629), Ni(98)
18. Cr(1,074), Ni(134)
19. Cr(552), Ni(84)
20. Cr(889), Ni(68)
21. Cr(220)

Sample discussed in sections describing other geochemically anomalous areas

Boundary of geochemically anomalous area

Boundary of adjacent geochemically anomalous area

(21) **Number of geochemically anomalous area**

Chromite occurrence (Winkler, Miller, and others, 1981)

Magmatic sulfide occurrence (Newberry, 1986)

Kv **Valdez Group (Late Cretaceous) of the Chugach terrane**

M_zm **McHugh Complex (Mesozoic) of the Chugach terrane**

Jm **Schist of Liberty Creek (Jurassic or older) of the Chugach terrane**

JPhc **Haley Creek metamorphic assemblage (Late Jurassic and Pennsylvanian and older ?) of the Wrangellia terrane**

Jbr **Border Ranges ultramafic-mafic assemblage (Middle Jurassic) of the Peninsular terrane**

Fault—Approximately located

Richardson Highway

Figure 28. Geochemically anomalous stream-sediment, and rock samples in the vicinity of Bernard and Dust Creeks (geochemically anomalous area 21), Valdez 1°×3° quadrangle, Alaska. Area is underlain by meta-sedimentary rocks of the Valdez Group, melange of the McHugh Complex, schist of Liberty Creek, and the Border Ranges mafic-ultramafic assemblage. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000. contour interval 1,000 ft.

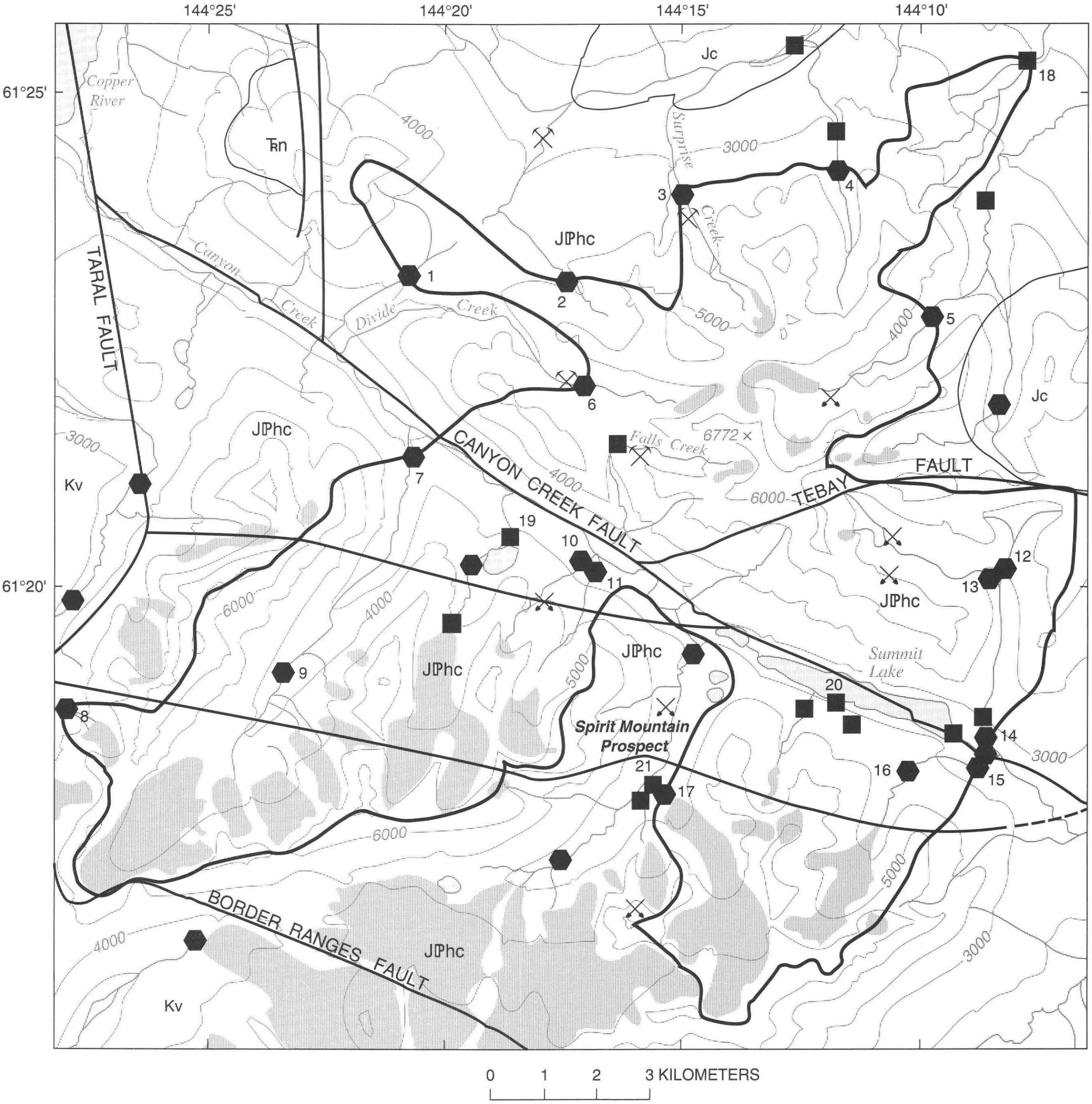


Figure 29 (above and facing column). Geochemically anomalous stream-sediment, heavy-mineral-concentrate, and stream-water samples in the Summit Lake area (geochemically anomalous area 22), Valdez 1°×3° quadrangle, Alaska. Area is underlain by meta-sedimentary rocks of the Valdez Group, the Haley Creek metamorphic assemblage, and the Chitina Valley batholith. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

A number of the sediment anomalies stand out as significant. The sample from the creek southeast of peak 6772 contains 150 ppm Co, the highest cobalt concentration from the AMRAP study. A copper- and nickel-bearing mineral occurrence within the drainage basin (Winkler, Miller, and others, 1981) is the obvious source for the anomaly. To the northeast of peak 6772, a sediment sample contains 3,000 ppm Ba and 190 ppm Zn and anomalous amounts of cobalt, copper, and nickel. Upstream parts of the watershed are likely to contain disseminated or massive sulfide occurrences. To the south of Summit Lake, a sediment sample contains 5 ppm Ag (the only unqualified silver value in

EXPLANATION

Alaska Mineral Resource Assessment Program sample–Values are in parts per million except Fe, which is in percent. Values are for sediment samples except for those accompanied by subscript "c," which are for concentrate samples

1. Co(100), Au_c(<20)
2. B(300), Cu(200)
3. B(300), Co(100), Cr(700), Cu(300)
4. Co(100), Cr(700), Ni(200)
5. Ba(3,000), Co(100), Cu(200), Ni(200), Zn(190), Au_c(<20)
6. Co(100), Cu(200)
7. Cr(700), Au_c(<20)
8. Au_c(<20), Mn_c(3,000)
9. Co(100), Au_c(<20), Fe_c(20), Mn_c(5,000), Mo_c(<10)
10. Co(100), Cu(200), Ni(200), Pb(100)
11. B(300), Co(100), Cu(200), Ni(200), Pb(100)
12. Co(100), Cu(200)
13. Co(150), Cr(700), Cu(200), Co_c(100)
14. Co(100), Au_c(<20)
15. Au_c(<20)
16. Ag(5), B(300), Pb(100)
17. Ag_c(2), Co_c(100), Fe_c(>20)

National Uranium Resource Evaluation sample—Sediment values are in parts per million, water values are in parts per billion. Values are for sediment samples except for that accompanied by subscript "w," which is for a stream-water sample

18. U_w(18.3)
19. Mn(2,209)
20. Au(0.27), Cu(105)
21. Cd(8)

Disseminated and massive copper-sulfide occurrence

Magmatic copper and nickel occurrence

Boundary of geochemically anomalous area

Kv **Valdez Group (Late Cretaceous) of the Chugach terrane**

Jc **Chitina Valley batholith (Late Jurassic) of the Wrangellia terrane**

JPhc **Haley Creek metamorphic assemblage (Late Jurassic and Pennsylvanian and older ?) of the Wrangellia terrane**

Ћn **Nikolai Greenstone (Late and (or) Middle Triassic) of the Wrangellia terrane**

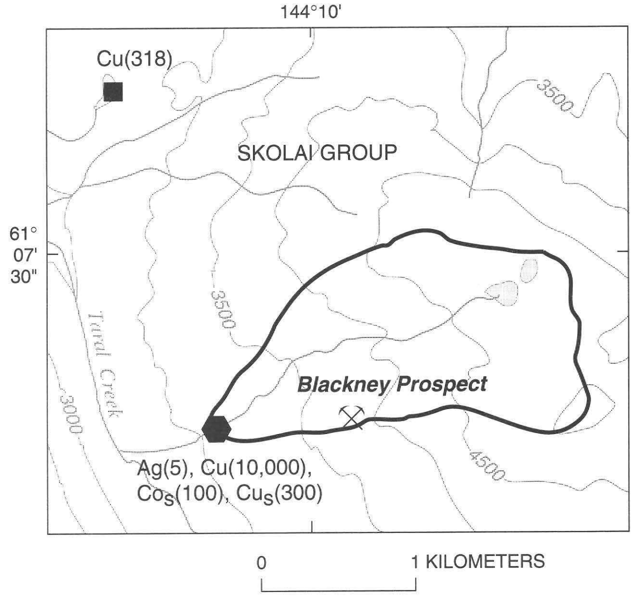
Fault—Approximately located

Geologic contact—Approximately located

Glacier

stream sediments from the AMRAP survey) and 100 ppm Pb; a heavy-mineral-concentrate sample collected in an adjacent basin contains 2 ppm Ag, 100 ppm Co, and more than 20 percent Fe (the highest iron value from the AMRAP survey).

A NURE stream-water sample from the small creek in the northeast corner of area 22 contains 18.3 ppb U, the highest concentration from the NURE survey. The



EXPLANATION

Alaska Mineral Resource Assessment Program sample—Values are in parts per million. Values are for a concentrate sample except those accompanied by a subscript "s,"which are for a sediment sample

National Uranium Resource Evaluation lake-sediment sample—Value is in parts per million

Boundary of geochemically anomalous area

Figure 30. Geochemically anomalous stream-sediment, heavy-mineral-concentrate, and lake-sediment samples near Taral Creek (geochemically anomalous area 23), Valdez 1°×3° quadrangle, Alaska. Area is underlain by mafic volcanic rocks of the Skolai Group of the Wrangellia terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 500 ft.

anomalous uranium may be derived from enrichments in pegmatitic dikes locally associated with upstream gabbroic rocks (Winkler, Silberman, and others, 1981).

Herreid (1970) collected 137 stream-sediment, soil, and rock chip samples in a 50-km^2 area around Summit Lake. Samples were analyzed for copper, nickel, lead, and zinc by atomic absorption and for 30 elements by emission spectrography. All anomalous stream-sediment samples are within the boundary of area 22 as defined by the AMRAP survey. Stream-sediment samples from below a number of pyrite-rich gossan zones on the ridge north of Summit Lake (in part corresponding with occurrence 106B of Winkler, Miller, and others, 1981) contained as much as 610 ppm Cu, 170 ppm Pb, and 650 ppm Zn. Sediment samples from the valley 3 km northwest of the Spirit Mountain prospect contained as much as 150 ppm Cu, 140 ppm Ni, and 200 ppm Zn. The only sample that contained detected silver (at the 1 ppm level) was from within a small north-facing drainage immediately east of the major watershed hosting the Spirit Mountain prospect. To the east, across the main stream valley from the prospect, a single stream-sediment sample contained 290 ppm Ni, 2,000 ppm Cr, and 200 ppm Sb. The lack of anomalous element values in stream-sediment samples downstream from the Spirit Mountain prospect, collected during both Herreid's survey and the AMRAP survey, may reflect both the small size of the occurrence relative to the large size of Canyon Creek, as well as the effects of glaciation (Herreid, 1970).

AREA 23— TARAL CREEK

A single concentrate sample from the headwaters of Taral Creek contains 10,000 ppm Cu and 5 ppm Ag (fig. 30). The corresponding stream sediment contains an anomalous amount of cobalt and copper. A NURE lake-sediment sample collected 2 km northwest of area 23 contains 318 ppm Cu, the highest concentration from the NURE geochemical survey. The country rock in area 23 consists of mafic volcanic rocks of the Wrangellia terrane. The abundant copper clearly represents the accumulation of pyrite and chalcopyrite weathered from the upstream quartz veins of the Blackney copper prospect (Moffit, 1914).

AREA 24—HALLET RIVER–ICEBERG LAKE

Nine NURE stream-sediment samples delineate an area of anomalous zinc and antimony and, less commonly, silver, magnesium, cobalt, nickel, copper, chromium, or titanium between Iceberg Lake and the Hallet River (fig. 31). The area is dominantly underlain by melange of the McHugh Complex; subordinate amounts of schist of Liberty Creek are also present. Four stream-sediment samples collected during the NURE survey contain 5–15 ppm Sb, and three sediment samples contain 244–276 Zn. The only sample from the NURE survey with detected silver, 5 ppm, was collected on the east side of the Hallet River. There are no prospects in the area, and stream-sediment and heavy-mineral-concentrate samples collected in the same area during the AMRAP survey generally lack anomalous element values. The source for the anomalies is uncertain, but stibnite-bearing quartz veins may be present.

AREA 25—KLANELNEECHENA CREEK

Rocks in area 25 consist of the Border Ranges mafic-ultramafic assemblage of the Peninsular terrane, melange of the McHugh Complex, and high-grade metamorphic rocks of the Wrangellia terrane. Data from three sample sites along the east side of Klanelneechena Creek in the northern half of area 25 suggest the upstream presence of precious-metal mineral occurrences (fig. 32). The concentrate sample at one site contains 2.5 ppm Au and at the second site 5 ppm Ag, and the sediment sample from the third site contains 0.1 ppm Au. One of the concentrate samples contains 1,000 ppm B, and sediment samples from all three sites contain anomalous boron. A value of 1,000 ppm B for one of these sediment samples was the highest from the AMRAP survey. The elevated boron values, coupled with the precious-metal anomalies, may indicate that tourmaline is associated with gold-bearing quartz veins.

Many sediment samples from the AMRAP and NURE surveys in drainages underlain by rocks of the Peninsular and Wrangellia terranes from both the north and south parts of area 25 are anomalous in iron, cobalt, copper, chromium, or vanadium. Concentrations of as much as 150 ppm Co and 300 ppm Cu are the highest from the AMRAP survey. Because of the mafic element enrichments, factor analysis identified many of the sediments from area 25 as anomalous onto factors 1 and 3. Anomalous factor scores onto factors 3 and 6 for many of the concentrate samples reflect elevated concentrations of vanadium, calcium, chromium, and scandium. The mafic element anomalies in area 25 are believed to represent high geochemical background values for the high-grade metamorphic rocks and the abundant lenses of ultramafic rock reported by Winkler, Silberman, and others (1981).

AREA 26—NELCHINA GLACIER

Area 26 is on the east side of Nelchina Glacier and is centered around the Border Ranges fault system (fig. 33). The north side of the area is underlain by mafic plutonic rocks of the Nelchina River Gabbronorite. The southern part of the area is underlain by a melange that contains blocks of both McHugh Complex melange and serpentinite (Winkler, Silberman, and others, 1981). Winkler, Miller, and others (1981) identified serpentinized ultramafic rocks from the divide south of Barnette Creek as favorable host rocks for disseminated and podiform chromite occurrences.

A mafic dike from the Border Ranges ultramafic-mafic assemblage contains 15 percent Fe, 10 percent Mg, 5 ppm Ag, 1,000 ppm Co, 1,500 ppm Cr, 28,000 ppm Cu, 3,000 ppm Ni, and 0.55 ppm Au (Miller and others, 1982). Ultramafic and serpentinized rocks from the assemblage and melange to the south contain as much as 10 percent Fe, >10 percent Mg, 200 ppm B, >5,000 ppm Cr, 340 ppm Cu, and 1,000 ppm Ni (Miller and others, 1982). A sample of a syenite dike from the south-central part of the area contains 5,000 ppm Ba, 3,000 ppm Cr, and 500 ppm Ni (Miller and others, 1982). Newberry (1986) described disseminations and irregular masses of magmatic pyrrhotite, chalcopyrite, and pentlandite in a layered gabbronorite from the headwaters of Barnette Creek. Analysis of the sulfide-rich igneous rock indicated 2,140 ppm Cu, 237 ppm Ni, and 0.2 ppm Ag. A grab sample of serpentinized

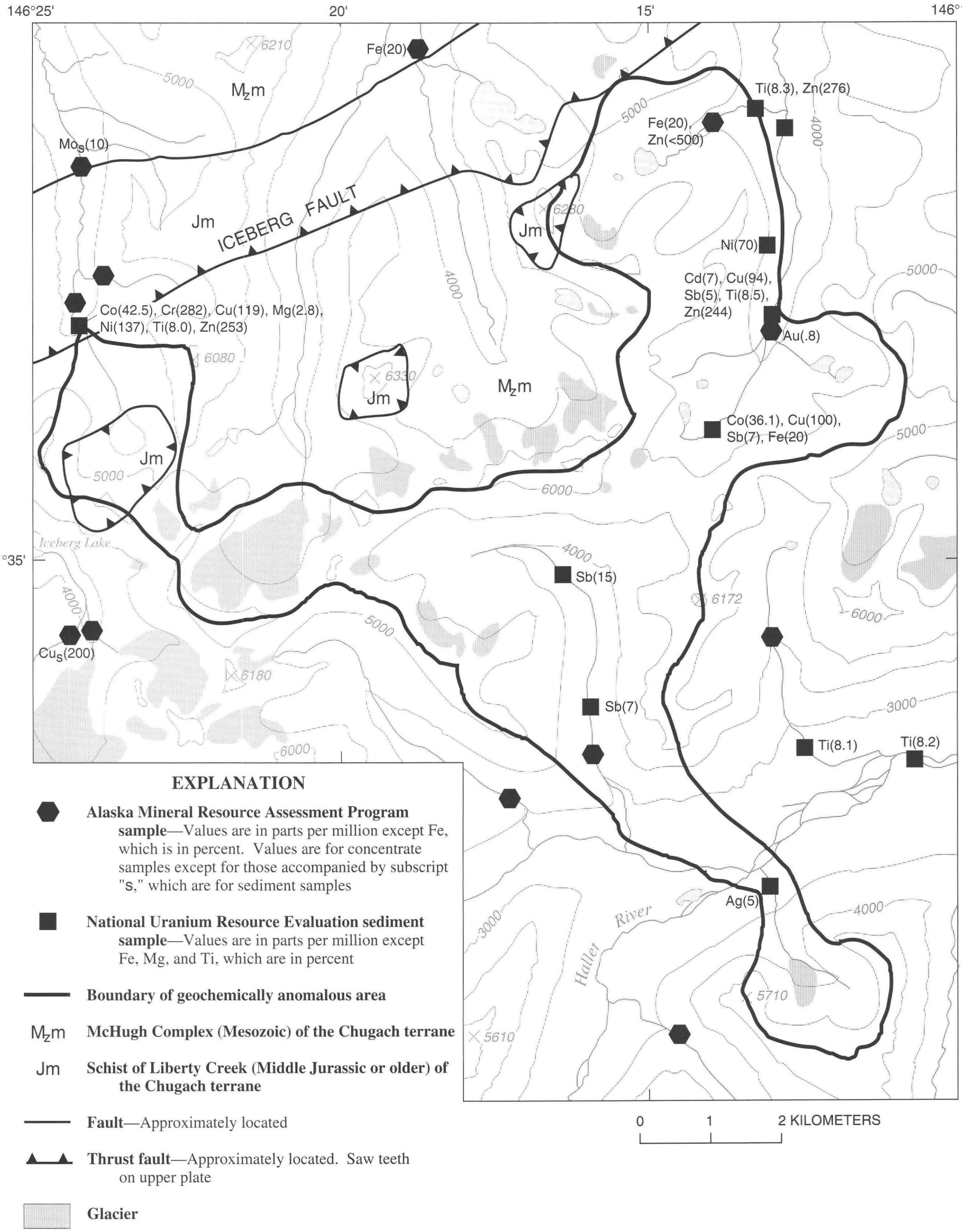
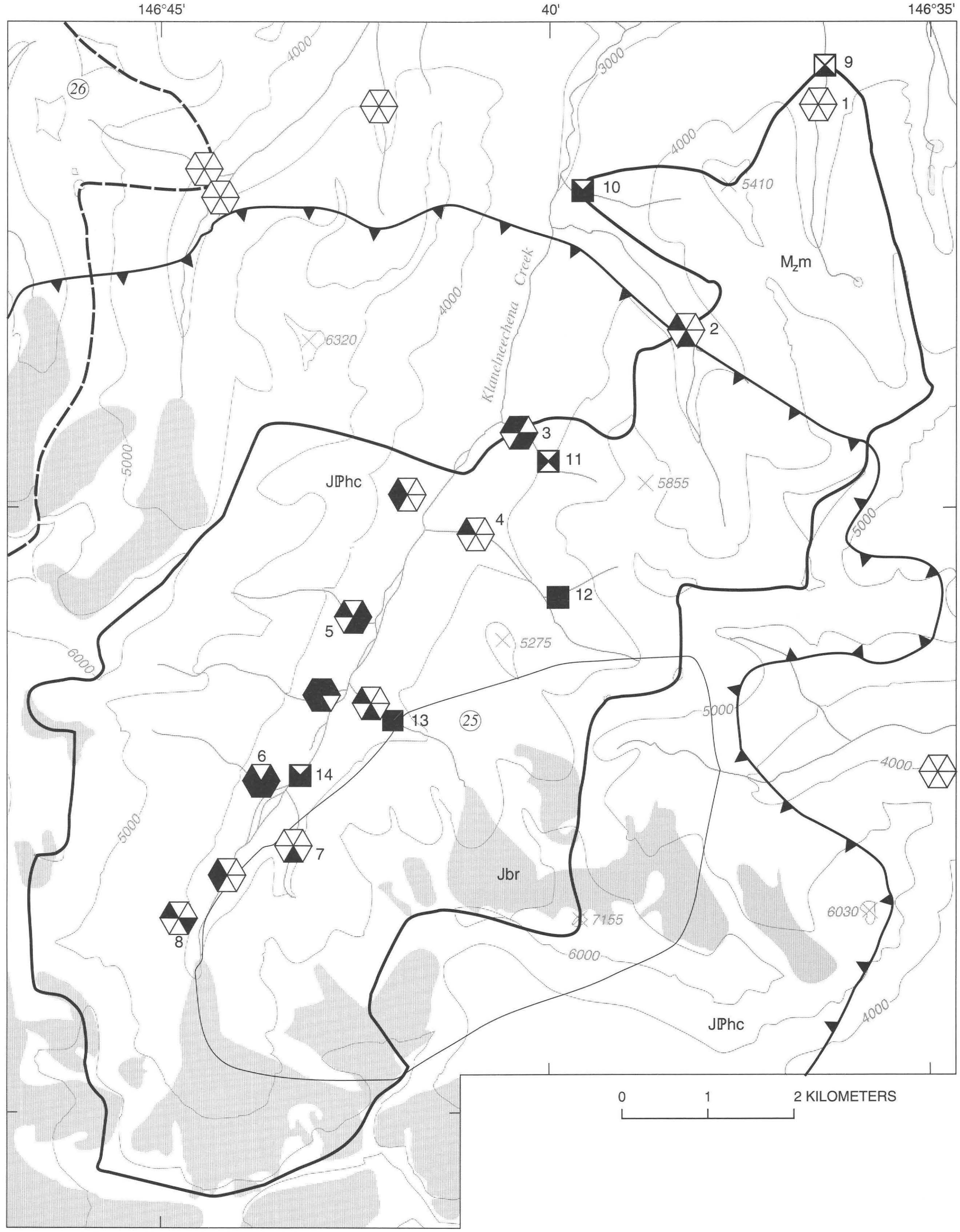


Figure 31. Geochemically anomalous stream-sediment and heavy-mineral-concentrate samples between Iceberg Lake and the Hallet River (geochemically anomalous area 24), Valdez 1°×3° quadrangle, Alaska. Area is underlain by melange of the McHugh Complex and the schist of Liberty Creek, both components of the Chugach terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.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Klanelneechena Creek
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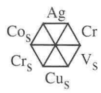
1
2 KILOMETERS

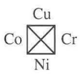
EXPLANATION



Alaska Mineral Resource Assessment Program sample–Values are in parts per million except for Fe, which is in percent. Values are for concentrate samples except those accompanied by subscript "s," which are for sediment samples

Category	Map Symbol	Ag	Cr	V	Cu_s	Cr_s	Co_s
Anomalous	▼	5	1,000	700	200–300	700–1,000	100–150

Additional anomalous values: 1, Au(2.5), B_s(300); 2, Au_s(0.1), B_s(500); 3, B(1,000), B_s(1,000); 4, B_s(300); 5, Ni_s(200); 6, Fe_s(20), Ni_s(300); 7, Fe(20); 8, Ni_s(200)



National Uranium Resource Evaluation sediment sample–Values are in parts per million except for Fe and Mg, which are in percent

Category	Map Symbol	Cu	Cr	Ni	Co
Anomalous	▼	94–127	163–315	65–134	42.0–52.4

Additional anomalous values: 9, Zn(263); 10, Fe(8.3), Mg(3.2), V(298), W(29); 11, Fe(8.4), Mg(3.5), V(292); 12, Fe(8.5), Mg(3.4), V(291); 13, Fe(8.7), Mg(3.7), V(314); 14, Fe(8.1), Mg(3.0), V(291)

Boundary of geochemically anomalous area

Boundary of adjacent geochemically anomalous area

(25) **Number of geochemically anomalous area**

M_zm **McHugh Complex (Mesozoic) of the Chugach terrane**

JPhc **Haley Creek metamorphic assemblage (Late Jurassic and Pennsylvanian and older ?) of the Wrangellia terrane**

Jbr **Border Ranges ultramafic-mafic assemblage (Middle Jurassic) of the Peninsular terrane**

Thrust fault—Approximately located. Saw teeth on upper plate

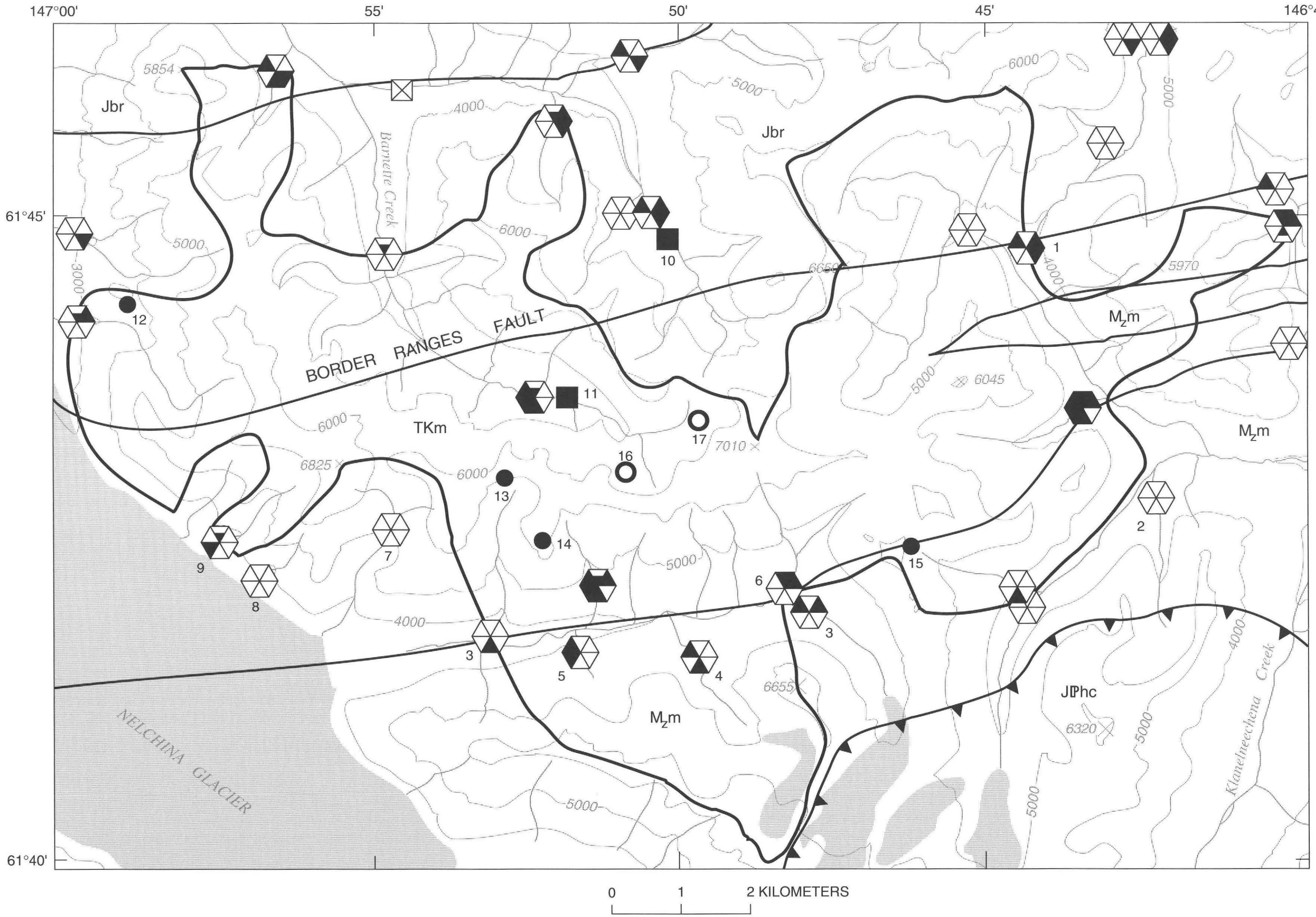
Geologic contact—Approximately located

Glacier

Figure 32 (above and facing page). Geochemically anomalous stream-sediment and heavy-mineral-concentrate samples from along Klanelneechena Creek (geochemically anomalous area 25), Valdez 1°×3° quadrangle, Alaska. Area is underlain by melange of the McHugh Complex of the Chugach terrane, the Haley Creek metamorphic assemblage, and the Border Ranges ultramafic-mafic assemblage. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

gabbro containing 5–10 percent magnetite and minor pyrite, from the same general area, contained 134 ppm Co and 834 ppm Ni (Newberry, 1986).

Area 26 is defined by both AMRAP sediment and concentrate samples that have anomalous chromium. Chromium values are generally 700 ppm in stream-sediment samples and 1,000–2,000 ppm in heavy-mineral-concentrate samples. Many of the sediment samples also contain 100 ppm Co, 200 ppm Cu, 200–300 ppm Ni, and 700–1,000 ppm V. Both sample media contain relatively high concentrations of magnesium and calcium. Similar to area 25, factor analysis studies showed that sediment samples have high scores for factors 1 and 3 and concentrates have high scores for factor 6. NURE stream-sediment samples from this area are also commonly anomalous in cobalt, chromium, and nickel. Chromium values of 3,000 ppm and >5,000 ppm for AMRAP sediment samples southwest and southeast of peak 6045 indicate the most favorable location for chromite-bearing mineral occurrences. Sutley and others (1990) noted chromium concentrations of >5,000 ppm in stream-sediment samples within 1 km of the Bernard Mountain chromite deposit in the eastern side of the Valdez quadrangle. Similar occurrences may be present near peak 6045.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TKm
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BORDER RANGES FAULT
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Barnette Creek
Klanelneechena Creek
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6825
7010
6650
6045
5970
6655
6320
6000
5000
4000
3000
0 1 2 KILOMETERS

EXPLANATION

Cr, Cu, Co, Ni, V, Cr_c

Alaska Mineral Resource Assessment Program sample—Values are in parts per million except Fe, and Mg, which are in percent. Values are for sediment samples except those accompanied by subscript "c," which are for concentrate samples. Leaders (--), no value for that category

Category	Map symbol	Cr	Co	V	Cr_c	Ni	Cu
Slightly anomalous	▼ (small)	700–1,500	--	--	--	--	--
Anomalous	▼ (large)	3,000–>5,000	100	700–1,000	1,000–2,000	200–300	200

Additional anomalous values: 1, Au_c(0.6); 2, Mn(3,000); 3, B(500); 4, Fe_c(20); 5, Ag(<0.5), Mo(10); 6, Mg(10); 7, B_c(1,000); 8, B(700), B_c(1,000); 9, B_c(500)

● **Alaska Mineral Resource Assessment Program rock sample**—Values are in parts per million except Fe, and Mg, which are in percent
12. Mafic dike: Ag(5), Au(0.55), Co(1,000), Cr(1,500), Cu(28,000), Fe(15), Mg(10), Ni(3,000)
13. Pyroxenite: Cr(3,000), Cu(340)
14. Serpentinite: B(200), Cr(>5,000), Cu(150), Fe(10), Mg(>10), Ni(700). Dunite: Cr(5,000), Ni(1,000)
15. Syenite: Ba(5,000), Cr(3,000), Ni(500)

Co, Ni, Cr, Cu

National Uranium Resource Evaluation sediment sample–Values are in parts per million except Fe, which is in percent

Category	Map symbol	Co	Cr	Cu	Ni
Anomalous	▼	44.7–46.6	196–425	105	74–76

Additional anomalous values: 10, Fe(8.1), Sb(13), V(260); 11, Fe(9.7), V(381)

○ **Rock sample of Newberry, (1986)**—Approximately located. Values are in parts per million
16. Serpentinized gabbro: 5–10 percent magnetite and minor pyrite, Co(134), Ni(834)
17. Sulfide-rich igneous rock: Ag(0.2), Cu(2,140), Ni(237)

Boundary of geochemically anomalous area

TKm **Melange (Tertiary or Cretaceous) of the Chugach terrane**

Mzm **McHugh Complex (Mesozoic) of the Chugach terrane**

JPhc **Haley Creek metamorphic complex (Late Jurassic and Pennsylvanian and older ?) of the Peninsular terrane**

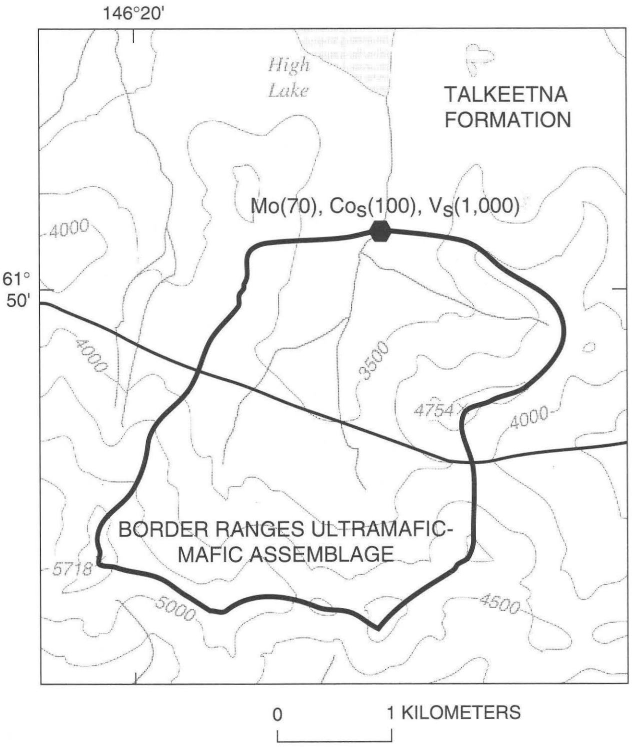
Jbr **Border Ranges ultramafic-mafic assemblage (Middle Jurassic) of the Peninsular terrane**

Fault—Approximately located

Thrust fault—Approximately located. Saw teeth on upper plate

Glacier

Figure 33. Geochemically anomalous stream-sediment, heavy-mineral-concentrate, and rock samples to the east of Nelchina Glacier (geochemically anomalous area 26), Valdez 1°×3° quadrangle, Alaska. Area is underlain by melange sequences of the Chugach terrane, the Haley Creek metamorphic assemblage, and the Border Ranges ultramafic-mafic assemblage. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.



EXPLANATION

Alaska Mineral Resource Assessment Program sample—Values are in parts per million. Values are for a concentrate sample except those accompanied by subscript "S," which are for a sediment sample

Boundary of geochemically anomalous area

Fault—Approximately located

Figure 34. Location of AMRAP sample site south of High Lake (geochemically anomalous area 27), Valdez 1°×3° quadrangle, Alaska, characterized by anomalous molybdenum in the heavy-mineral concentrate and anomalous cobalt and vanadium in the corresponding stream sediment. Area is underlain by rocks of the Talkeetna Formation and the Border Ranges ultramafic-mafic assemblage. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

AREA 27—HIGH LAKE

A single concentrate sample collected to the south of High Lake contains 70 ppm Mo, the highest molybdenum value from the AMRAP study (fig. 34). The corresponding stream-sediment contains 100 ppm Co and 1,000 ppm V. The sampled stream drains rocks of both the Talkeetna Formation and the Nelchina River Gabbronorite. The source of the anomalies is uncertain; however, the sampled site is in a swampy area along the south side of the High Lake, and the anomalies may simply reflect a high concentration of organic material.

AREA 28—KOTSINA RIVER MINING DISTRICT

In the northeast part of the Valdez quadrangle, abundant stream-sediment and heavy-mineral-concentrate sample anomalies (fig. 35) are associated with copper occurrences in the western part of the Kotsina River mining district (area 28). The vein and breccia occurrences are hosted by Triassic limestone and the Nikolai Greenstone of the Wrangellia terrane. Copper values as high as 340 ppm in stream sediments and 2,000 ppm in heavy-mineral concentrates reflect accumulations of eroded copper sulfide and oxide minerals.

Boron and vanadium are also characteristically anomalous in many of the stream sediments. The anomalous vanadium likely reflects the high background concentration for the element in the Nikolai Greenstone; the source of the boron enrichment is uncertain but may be the scattered felsic intrusive rocks. NURE sediment samples from the mouths of Pass, Clear, and Sheep Creeks all contain 3 ppm Sb, perhaps indicative of tetrahedrite, which is abundant in the sulfide-rich occurrences of the Kotsina district.

The concentrate sample collected from Pass Creek on the eastern edge of area 28, although lacking anomalous copper, contains 5 ppm Au and anomalous iron, barium, arsenic, zinc, molybdenum, and nickel. The NURE sediment sample collected near the mouth of Sheep Creek contains 0.17 ppm Au. Placer and lode gold occurrences are reported near the mouth of Copper Creek (Winkler, Miller, and others, 1981), immediately northeast of area 28, and placers are present along Benito Creek to the south. Therefore, minor gold placers and (or) lodes are also likely to be present within area 28.

The concentrate sample from Pass Creek and one sample just to the west contain≥ ≥5,000 ppm Ba, suggesting the presence of barite in occurrences to the east of Alice Peak. Barite is a common gangue phase in the occurrences within the Kotsina River district (Moffit and Mertie, 1923). A value of 960 ppm Zn in a concentrate sample from the stream on the south side of Alice Peak likely reflects sphalerite associated with the copper-dominant mineral occurrences. Although the source of the anomalies is uncertain, both AMRAP sediment and concentrate samples from the north half of area 28 are consistently enriched in molybdenum. A value of 50 ppm Mo for the stream sediment collected at the northwest corner of area 28 is the highest concentration determined for all samples from the AMRAP survey. Similar to the anomalous boron, the molybdenum may have been derived from the small granodiorite and quartz latite bodies and the porphyritic dikes that have locally intruded the limestone and greenstone.

AREA 29—WRANGELL MOUNTAINS

Most of the northeast corner of the Valdez quadrangle is underlain by volcanic rocks of the Wrangell Lavas. There are no known mineral occurrences in these rocks within the study area; however, most concentrate samples collected from drainages underlain by these units contain 20 percent Fe, 7–10 ppm Mg, 3,000–5,000 ppm Mn, 100 ppm Co, and (or) 300–500 ppm Ni (fig. 36). The anomalous manganese is a major contributor to the high factor 4 scores calculated for concentrate samples from the area. Factor 6 scores for samples from the area are also commonly anomalous, indicating high concentrations of chromium and scandium. Corresponding stream-sediment samples lack anomalous element values. The source for the anomalies in the heavy-mineral-concentrate samples is believed to be weakly magnetic ferromagnesian silicate minerals and other non-magnetic mafic mineral grains that have been weathered from the pyroxene-rich andesite flows.

AREA 30—DADINA RIVER

A single concentrate sample collected from a tributary of the Dadina River in the northeast corner of the Valdez quadrangle is highly anomalous in zinc (fig. 37). The sample contains 950 ppm Zn but only background concentrations of all other elements. Surrounding AMRAP concentrate samples, as well as corresponding stream-sediment samples, also lack element anomalies; however, the only NURE lake-sediment sample containing detected silver (4 ppm) was collected just 3 km to the southeast. The watershed from which the sample with the anomalous zinc was derived is underlain by the dominantly andesitic lava of the Wrangell volcanic field. The source for the zinc enrichment in the concentrate sample is unknown.

AREA 31—COPPER RIVER

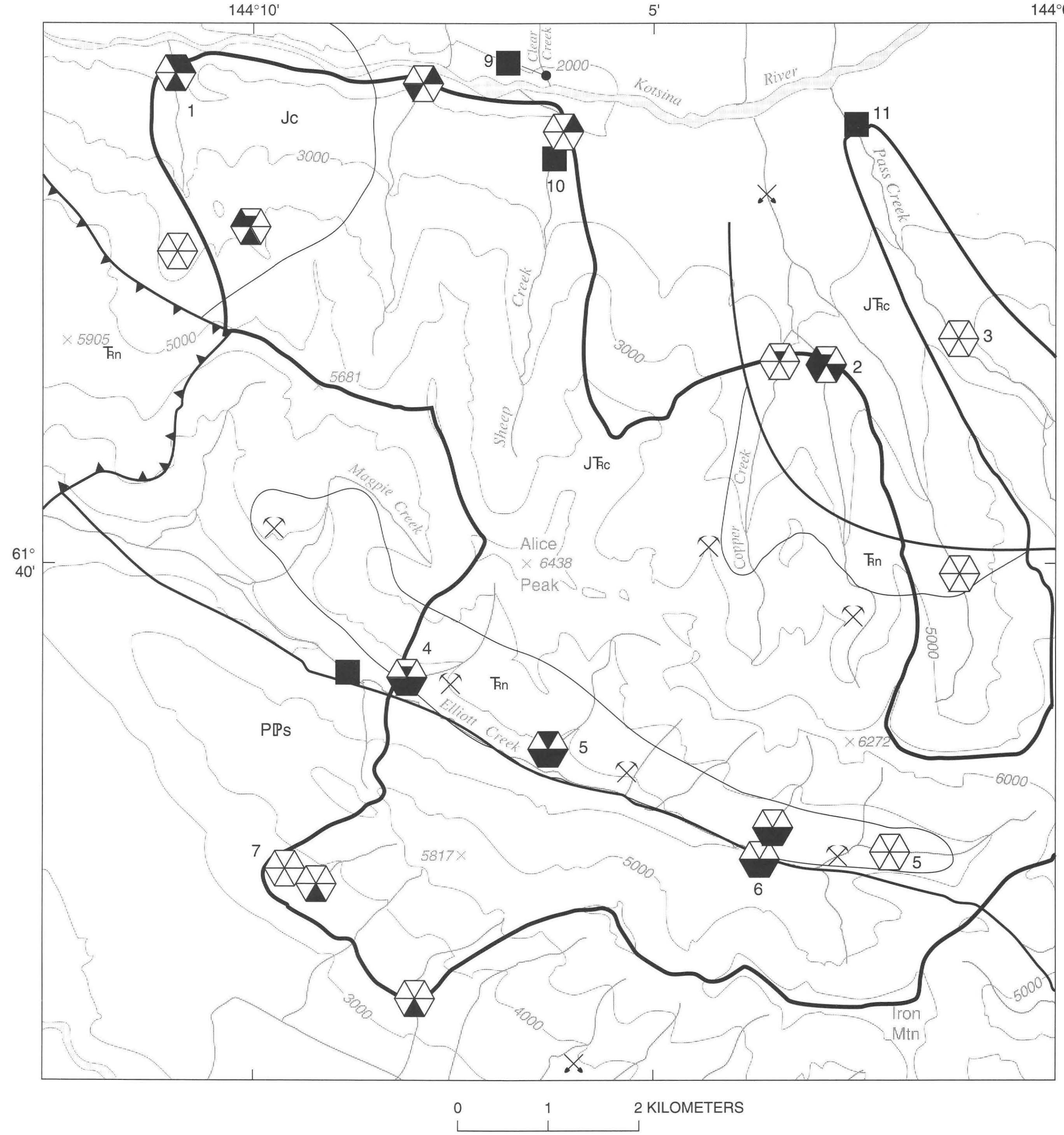
An area in the Copper River Lowlands, mostly along the east side of the Copper River, is delineated by numerous NURE lake-water samples that have high concentrations of uranium (fig. 38). Seven samples in area 31 contain >2 ppb U. The lake-water sample from the center of the northern edge of the area contains 9.73 ppb U, the highest uranium value in the NURE survey. The area is almost entirely underlain by Quaternary surficial deposits, although the Wrangell Lavas is exposed along many of the stream valleys. The source for the anomalies is uncertain but may reflect complexing of uranium by organic matter or phosphates in the lake waters.

CONCLUSIONS

Stream-sediment and heavy-mineral-concentrate samples that have anomalous concentrations of gold and silver define numerous areas within the Valdez 1°×3° quadrangle in south-central Alaska that are geochemically favorable for the presence of gold-bearing mesothermal quartz veins. Arsenic, boron, bismuth, cobalt, copper, iron, molybdenum, nickel, lead, tungsten, and (or) zinc are also commonly enriched in many of these samples. Much of the area underlain by greenschist-facies metasedimentary rocks of the Valdez Group of the Chugach terrane is favorable for these small precious-metal-bearing veins. The veins could be high grade but probably are of very low tonnage, typical of such hydrothermal systems throughout the Kenai and Chugach Mountains. Where felsic dikes or small stocks intrude the Valdez Group turbidite sequences, veins may be preferentially hosted in the more brittle igneous rocks. A few small areas underlain by sedimentary units of the Orca Group (areas 1a and 1b), metamorphosed units of the southern Wrangellia terrane margin (part of area 20), type Wrangellia terrane (part of area 28), and both the McHugh Complex of the Chugach terrane and metamorphic rocks of the Peninsular terrane (east side of Klanelneechena Creek in area 25) may also contain auriferous veins.

Polymetallic quartz veins, lacking anomalous gold concentrations but characterized by anomalous concentrations of many of the base metals, likely crop out in a number of areas underlain by rocks of the Chugach terrane. Metasedimentary rocks of the Valdez Group west of Port Valdez (area 2), along the south side of the East Fork of the Bremner River (area 11), around Mt. Ourand (area 16), and between the Tonsina River and Black Mountain (areas 18 and 19) are geochemically favorable for the presence of polymetallic veins. Rocks of the McHugh Complex between Hallet River and Iceberg Lake (area 24) may contain veins enriched in stibnite and (or) zinc. These polymetallic veins are probably similar in size and origin to the auriferous mesothermal veins but for some reason do not contain anomalous amounts of gold. The lack of significant amounts of extractable gold encountered by hydrothermal fluids along their flow path may account for the distinction between the mesothermal gold vein and polymetallic vein systems.

Much of the area south of the Lowe and Tasnuna Rivers is characterized by geochemical signatures favorable for the presence of volcanogenic sulfide occurrences (areas 5 and 6). The area is underlain by intercalated metasedimentary and mafic metavolcanic rocks of the Valdez Group. Scattered mines, prospects, and occurrences dominated by iron- and copper-rich massive sulfides, disseminated sulfides, and sulfide-bearing quartz veins that contain metals remobilized from adjacent volcanogenic sulfides are present in the



region. Widespread concentrate samples, and less commonly stream-sediment samples, are characterized by anomalous amounts of silver, gold, cobalt, copper, iron, and nickel (±B, Bi, Pb, W). Stream-sediment samples from the Summit Lake area (area 22) that contain anomalous amounts of copper and cobalt (±Cr, Ni, Pb) define the extent of both volcanogenic and magmatic copper-dominant occurrences in that part of the southern Wrangellia terrane margin. Anomalous amounts of cobalt, iron, and zinc in samples collected between the headwaters of the Uranatina River and the "Scarp" benchmark (within and adjacent to area 20) probably reflect volcanogenic sulfides disseminated in the schist of Liberty Creek. An area along the eastern edge of the Valdez quadrangle that is favorable for the presence of

EXPLANATION

Alaska Mineral Resource Assessment Program sample—Values are in parts per million except for Fe, which is in percent. Values are for concentrate sample except those accompanied by subscript "s," which are for sediment samples. Leaders (--), no values for that category

Category	Map symbol	Cu	Mo_S	V_S	Cu_S	B_S	Zn_S
Slightly anomalous	▼	500–1,000	--	--	--	--	--
Anomalous	▼	1,500–2,000	<5–50	700–1,000	110–340	300–1,000	200

Additional anomalous values: 1, Cr(1,000), Mo(20); 2, Ba(>5,000); 3 Au(5.0), As(<500), Ba(>5,000), Fe(20), Mo(20), Ni(300), Zn(<500); 4, Zn(960), Co_S(100); 5, B(500); 6, B(500), Co_S(100); 7, As_S(<500)

National Uranium Resource Evaluation sediment sample—Values are in parts per million
9. Sb(3)
10. Au(0.17), Sb(3)
11. Sb(3), V(284)

Boundary of geochemically anomalous area

Copper occurrence (Winkler, Miller, and others, 1981)

Placer and lode gold prospect

Jc **Chitina Valley batholith (Late Jurassic) of the Wrangellia terrane**

JTRc **Marine clastic and carbonate rocks (Late or Middle Jurassic to Late Triassic) of the Wrangellia terrane**

TRn **Nikolai Greenstone (Late and (or) Middle Triassic) of the Wrangellia terrane**

PIPs **Skolai Group (Early Permian and Pennsylvanian) of the Wrangellia terrane**

Fault—Approximately located

Thrust fault—Approximately located. Saw teeth on upper plate

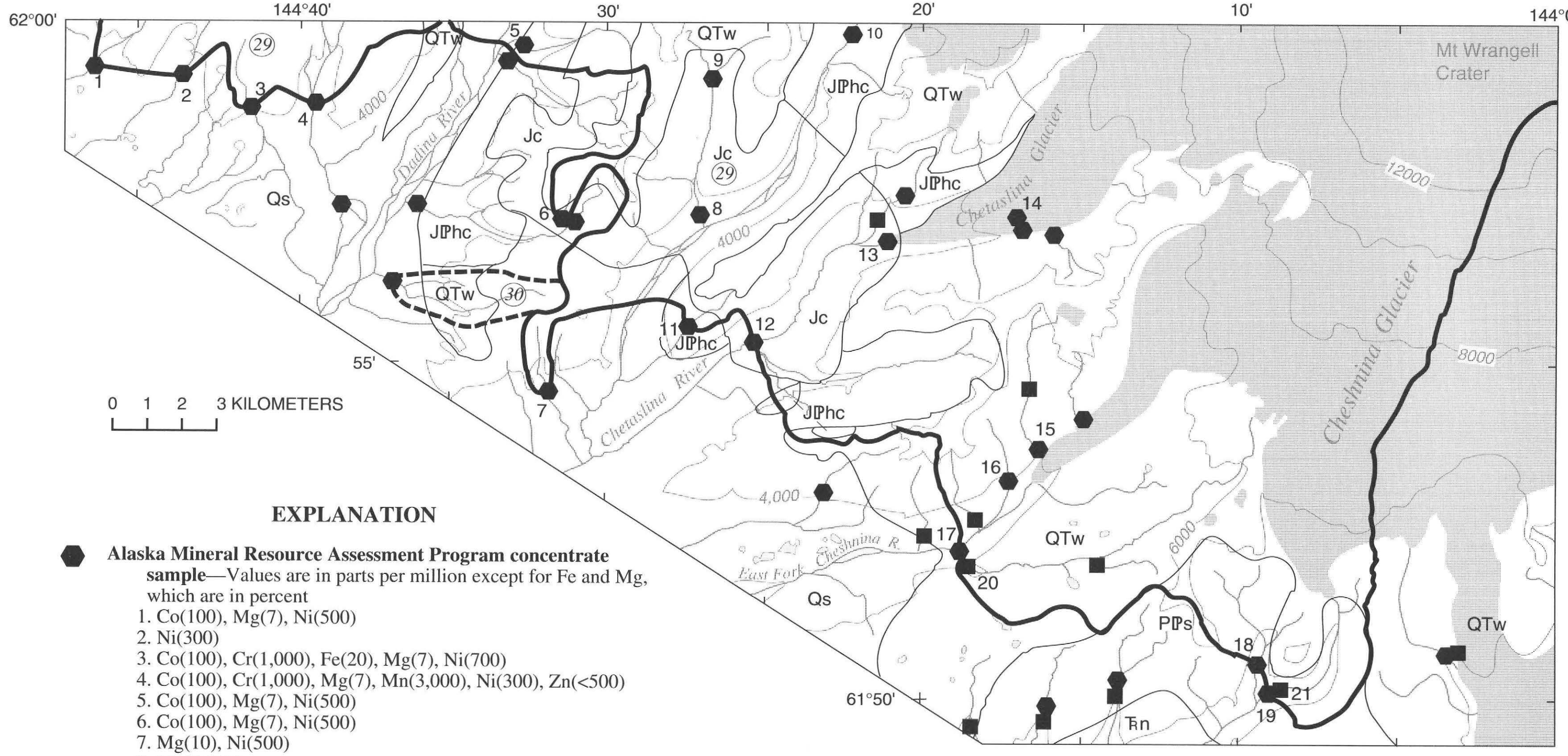
Geologic contact—Approximately located

Figure 35 (above and facing page). Geochemically anomalous stream-sediment and heavy-mineral-concentrate samples in and adjacent to the Kotsina River mining district (geochemically anomalous area 28), Valdez 1°×3° quadrangle, Alaska. Area is underlain by rocks of the Chitina Valley batholith, Skolai Group, Nikolai Greenstone, and Jurassic and Triassic marine units of type Wrangellia terrane. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 1,000 ft.

Kennecott-type copper occurrences (area 28) is defined by copper enrichments in both heavy-mineral-concentrate and stream-sediment samples.

Stream-sediment samples anomalous in chromium, iron, magnesium, nickel, and vanadium delineate a part of the Border Ranges ultramafic-mafic assemblage that is favorable for the presence of lenses and disseminations of chromite (area 21). An area underlain by rocks of the McHugh Complex and the Nelchina River Gabbronorite to the east of Nelchina Glacier (area 26) is also geochemically favorable for chromite occurrences. The area is defined by stream-sediment samples anomalous in calcium, cobalt, chromium, copper, magnesium, nickel, and vanadium and concentrate samples enriched in calcium, chromium, and magnesium. Manganese anomalies are noted in stream-sediment and (or) heavy-mineral-concentrate samples collected south of the Lowe River (area 5), in the Cleave Creek region (area 8), and in the southeast corner of the Valdez quadrangle (area 11 and the southern part of area 9). These anomalies, in samples derived from rocks of the Valdez Group, may reflect the presence of bedded manganese occurrences (especially where spatially associated with outcrops of metavolcanic rocks) or simply may reflect schist and phyllite locally enriched in manganese.

Consideration of NURE sediment and water data alone would have been of little use in defining areas of geochemical favorability for base- and precious-metal-bearing mineral occurrences. The common sampling of high-order rivers, erratic sample density, elevated lower determination limits for many metallic elements of interest, and relative small sampled volume (compared to the amount of material sampled for a heavy-mineral-concentrate sample) are problems with the NURE survey of the Valdez quadrangle. Gold and base-metal anomalies in NURE samples are scattered



EXPLANATION

Alaska Mineral Resource Assessment Program concentrate sample—Values are in parts per million except for Fe and Mg, which are in percent

1. Co(100), Mg(7), Ni(500)
2. Ni(300)
3. Co(100), Cr(1,000), Fe(20), Mg(7), Ni(700)
4. Co(100), Cr(1,000), Mg(7), Mn(3,000), Ni(300), Zn(<500)
5. Co(100), Mg(7), Ni(500)
6. Co(100), Mg(7), Ni(500)
7. Mg(10), Ni(500)
8. Mn(3,000)
9. Co(100), Ni(300)
10. Co(100), Fe(20), Mg(7), Mn(3,000), Ni(300), Zn(<500)
11. Mg(7), Ni(300)
12. Co(100), Mg(7), Mn(3,000), Ni(300)
13. Co(100), Fe(20), Mg(7), Mn(3,000), Ni(300)
14. Co(100), Fe(20), Mg(7), Mn(3,000), Ni(300)
15. Co(100), Fe(20), Mg(7), Mn(5,000), Ni(300), Zn(<500)
16. Co(100), Fe(20), Ni(300)
17. Co(100), Fe(20), Mg(7), Mn(3,000), Ni(300), Zn(<500)
18. Cu(500), Fe(20), Zn(<500)
19. Co(100), Mn(3,000), Ni(300)

National Uranium Resource Evaluation sediment sample—Values are in parts per million

20. Bi(6)
21. Co(35.6), Cr(213), Ni(103)

Boundary of geochemically anomalous area

Boundary of adjacent geochemically anomalous area

(29) **Number of geochemically anomalous area**

Qs **Surficial deposits, undivided (Quaternary)**

QTw **Wrangell Lava (Holocene to Miocene) of the Wrangellia terrane**

Jc **Chitina Valley batholith (Late Jurassic) of the Wrangellia terrane**

JPhc **Haley Creek metamorphic assemblage (Late Jurassic and Pennsylvanian and older ?) of the Wrangellia terrane**

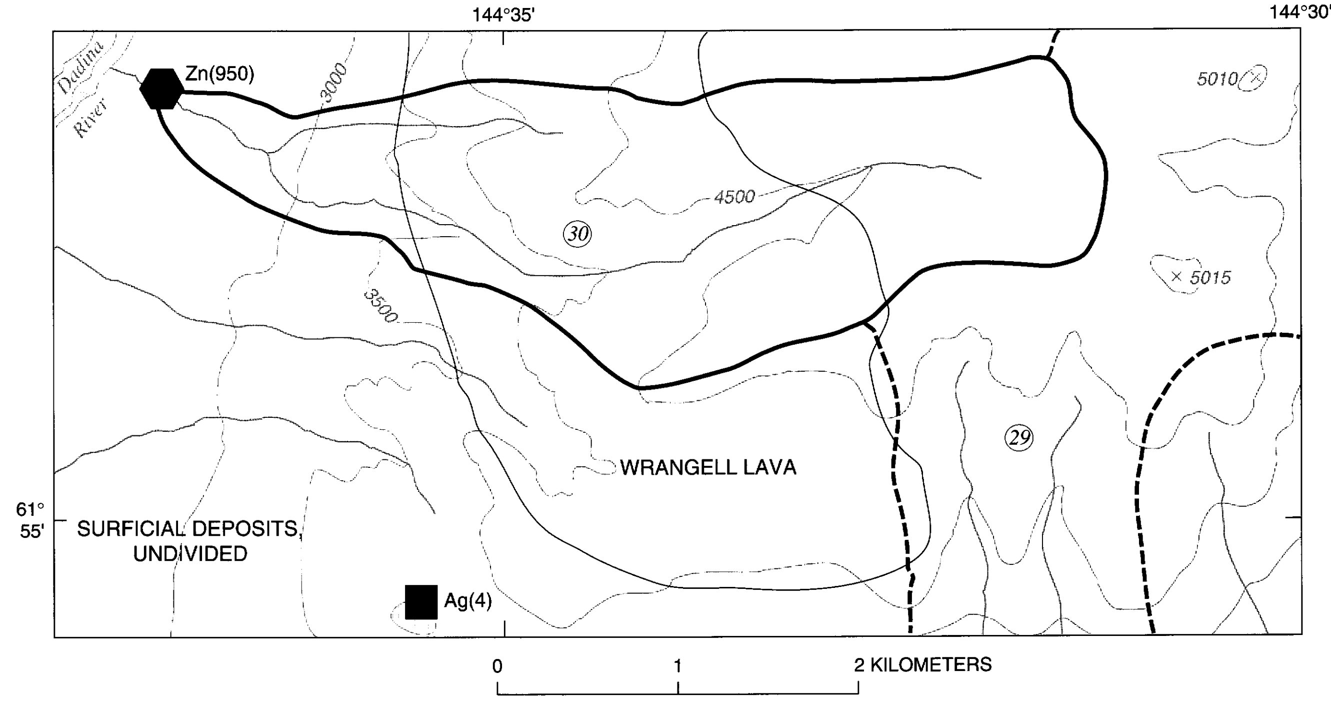
Ŧn **Nikolai Greenstone (Late and (or) Middle Triassic) of the Wrangellia terrane**

PPs **Skolai Group (Early Permian and Pennsylvanian) of the Wrangellia terrane**

Geologic contact—Approximately located

Glacier

Figure 36. Geochemically anomalous heavy-mineral-concentrate and stream-sediment samples within the Wrangell Mountains (geochemically anomalous area 29), Valdez 1°×3° quadrangle, Alaska. Area is underlain by Quaternary surficial deposits, Wrangell Lava, the Chitina Valley batholith, Haley Creek metamorphic assemblage, Nikolai Greenstone, and the Skolai Group. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 2000 ft.



EXPLANATION

- **Alaska Mineral Resource Assessment Program concentrate sample**—Value is in parts per million
- **National Uranium Resource Evaluation lake-sediment sample**—Value is in parts per million
- **Boundary of geochemically anomalous area**
- **Boundary of adjacent geochemically anomalous area**
- (30) **Number of geochemically anomalous area**
- **Geologic contact**—Approximately located

Figure 37. Location of sample site east of the Dadina River (geochemically anomalous area 30), Valdez 1°×3° quadrangle, Alaska, characterized by anomalous zinc in the heavy-mineral-concentrate sample. A lake-sediment sample collected south of area 30 contains anomalous silver. Area is underlain by Quaternary surficial deposits and Wrangell Lava. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 500 ft.

throughout the quadrangle, but no distinct patterns amenable to tract definition can be ascertained.

The NURE data do, however, show clusters of uranium-rich samples. Stream-sediment samples south of the Bremner River (area 10), as well as those immediately to the south in the Cordova quadrangle, contain 5.2–7.2 ppm U. In the Tiekel River–Stuart Creek area (area 14), stream-sediment samples contain as much as 21.5 ppm U, and stream-water samples contain as much as 8.9 ppb U. In both areas, uranium and rare earth element enrichments reflect abundant monazite, apatite, allanite, and other accessory silicate phases associated with felsic igneous rocks. In the Copper River Lowlands (area 31), a cluster of lake-water samples contain 2–10 ppb U. The source of these anomalies is uncertain.

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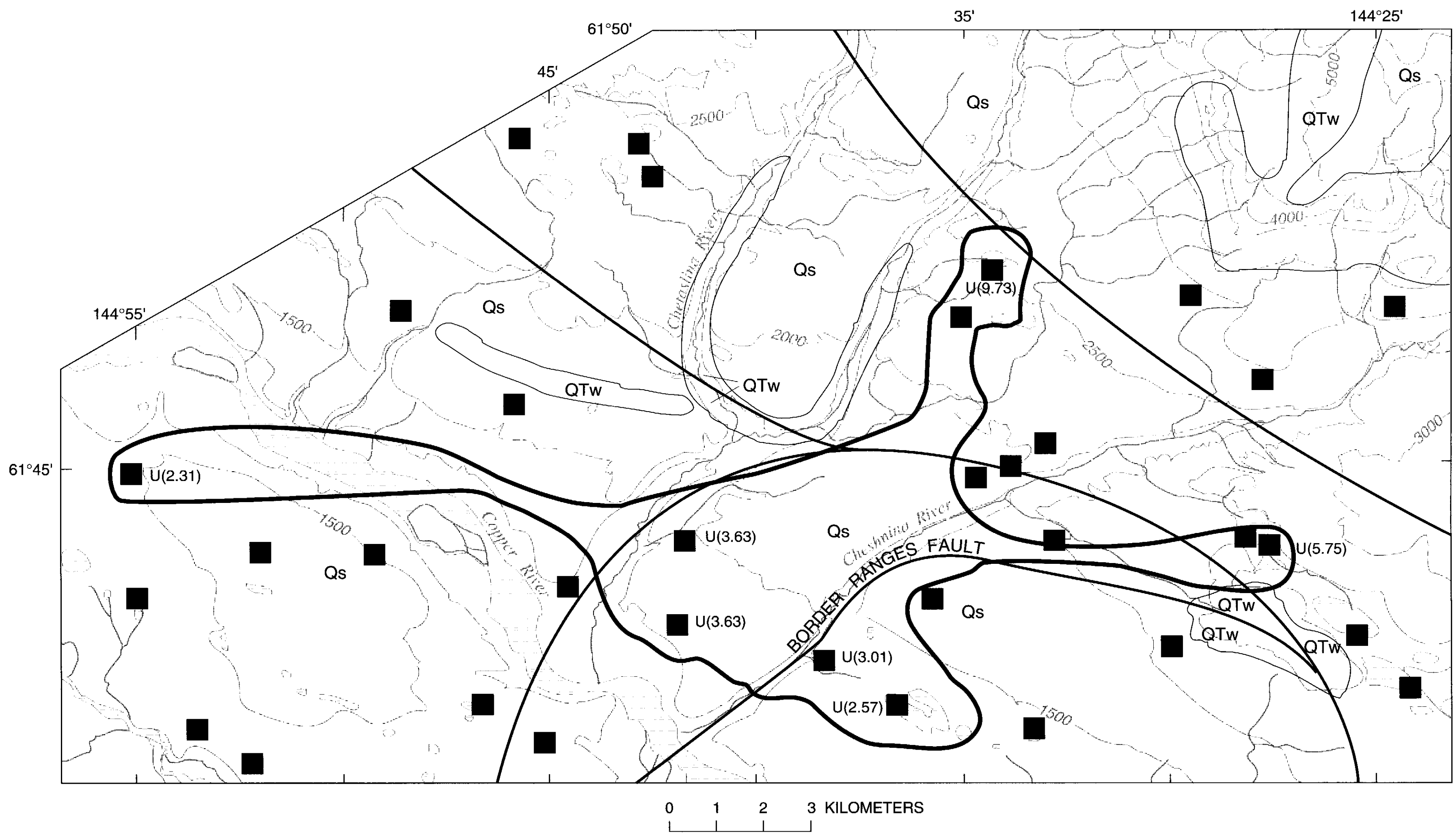

EXPLANATION

■ **National Uranium Resource Evaluation lake-water sample**—Values are in parts per billion

▬ **Boundary of geochemically anomalous area**

Qs **Surficial deposits, undivided (Quaternary)**

QTw **Wrangell Lava (Holocene to Miocene) of the Wrangellia terrane**

▬ **Fault**—Approximately located

— **Geologic contact**—Approximately located

Figure 38. Geochemically anomalous lake-water samples in a region underlain by Quaternary surficial deposits of the Copper River Lowlands (geochemically anomalous area 31), Valdez 1°×3° quadrangle, Alaska. Base map from U.S. Geological Survey Valdez, 1960, scale 1:250,000, contour interval 500 ft.

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