Interpretation of Reconnaissance Geochemical Data from the Healy Quadrangle, Alaska

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U.S. GEOLOGICAL SURVEY BULLETIN 1894

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE: 1990

For sale by the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center, Box 25425
Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

Light, Thomas D.
Interpretation of reconnaissance geochemical data from the Healy quadrangle, Alaska / by Thomas D. Light, Richard B. Tripp, and Harley D. King.

p. cm. – (U.S. Geological Survey bulletin ; 1894)
Includes bibliographical references.
Supt. of Docs. no.: I 19.3:1894
1. Geology—Alaska—Healy Region. 2. Geochemistry—Alaska—Healy Region. I. Tripp, R. B. II. King, Harley D. III. Title. IV. Series.
QE75.B9 no. 1894
[QE84]
557.3 s—dc20 89-600245
[557.98'6] CIP

STUDIES RELATED TO AMRAP

The U.S. Geological Survey is required by the Alaskan National Interest Lands Conservation Act (ANILCA, Public Law 96–487) to survey certain Federal lands to determine their mineral resource potential. Results from the Alaskan Mineral Resource Assessment Program (AMRAP) must be made available to the public and be submitted to the President and the Congress. This report presents an interpretation of geochemical data from the Healy quadrangle, Alaska.

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Interpretation of Reconnaissance Geochemical Data from the Healy Quadrangle, Alaska

By Thomas D. Light, Richard B. Tripp, *and* Harley D. King

INTRODUCTION

The Healy quadrangle, comprising about 6,400 square miles (16,600 square kilometers) in southern Alaska, lies 60 mi (miles) (90 km; kilometers) south of Fairbanks, Alaska and 120 mi (180 km) north of Anchorage, Alaska (fig. 1). The quadrangle is traversed by the central Alaska Range and includes the eastern one-third of Denali National Park. The George Parks Highway is a major north-south access route across the western part of the area, and the Denali Highway crosses the southern half of the quadrangle.

The Healy quadrangle covers the area from latitude 63° to 64° N., and from longitude 147° to 150° W. Topography in the area varies from steep, rugged mountainous terrain to low-lying flatlands. The highest elevation in the quadrangle is 12,339 ft (feet) (3,760 m; meters) at the peak of Mt. Deborah, and the lowest elevation is just over 1,000 ft (300 m) along the Nenana River at the north boundary of the quadrangle.

Manuscript approved for publication May 26, 1989

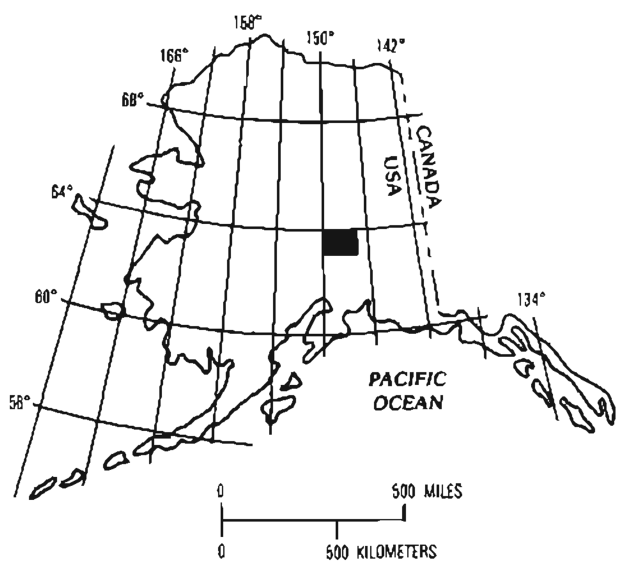


Figure 1. Index map of Alaska showing location of the Healy quadrangle (shaded area).

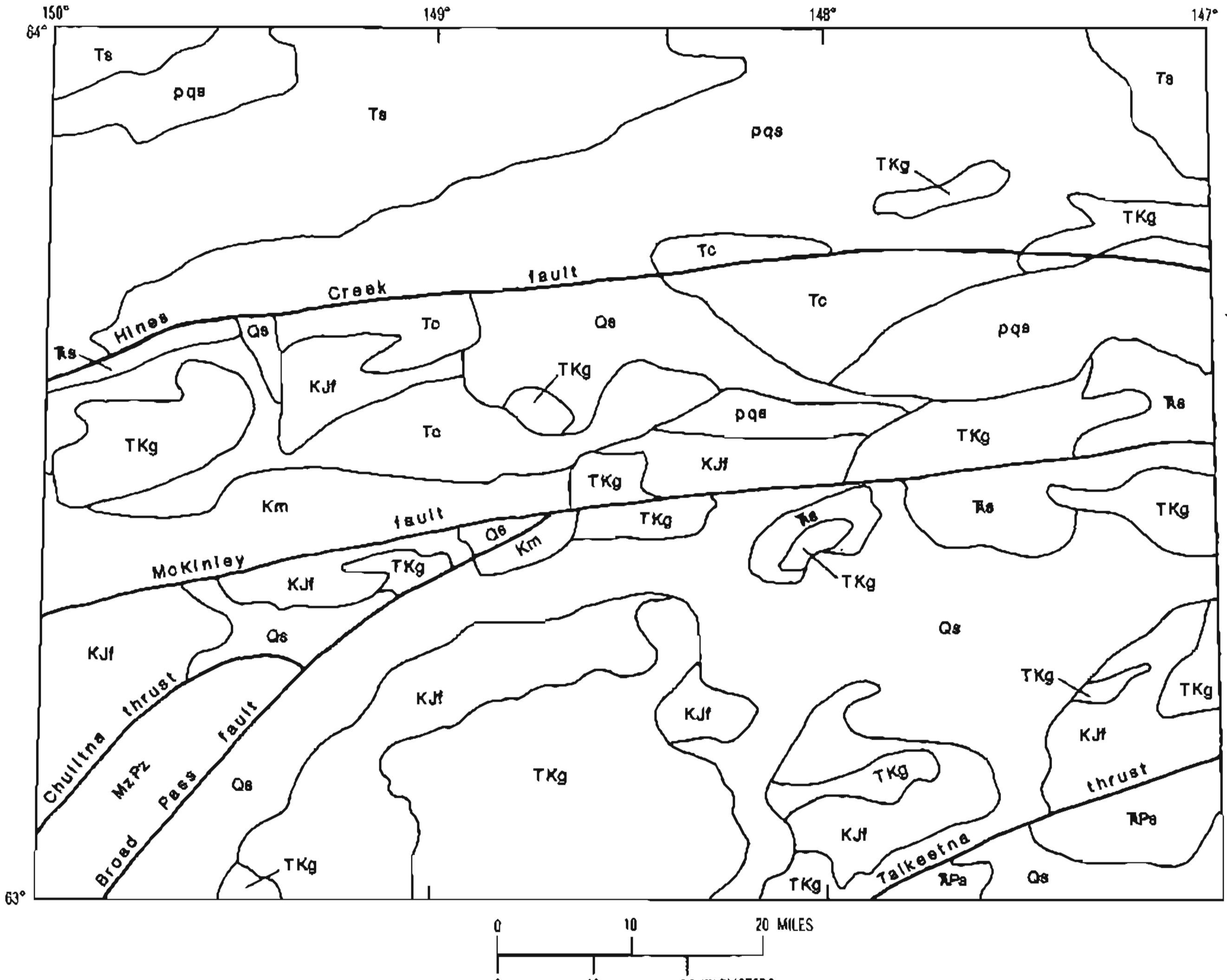
The U.S. Geological Survey conducted a reconnaissance geochemical survey of the Healy quadrangle in 1980, 1981, and 1982. Stream-sediment samples were collected at 1,064 sites, and heavy-mineral concentrate samples were collected at 1,045 of these sites. The stream-sediment samples and the nonmagnetic fraction of the heavy-mineral concentrate samples were analyzed for 31 elements by semiquantitative emission spectrography. In addition, most of the stream-sediment samples were analyzed by atomic absorption for Au and Zn, and some were analyzed for As, Cd, and Sb. Analytical data for the stream-sediment and heavy-mineral concentrate samples were reported by O'Leary and others (1984). A preliminary interpretation of factor analysis of these data was reported by Light (1985). The distribution of selected elements in geochemical samples was reported by King and others (1989) for stream sediments and by Light and others (1989) for heavy-mineral concentrates. Tripp and others (1989) reported the distribution of selected ore-related minerals in the nonmagnetic fraction of the heavy-mineral concentrates. The present study presents an interpretation of the distribution and associations of trace-element and mineralogical data from reconnaissance geochemical samples from the Healy quadrangle, Alaska.

REGIONAL GEOLOGIC SETTING

The Healy quadrangle is a geologically complex and diverse area along the accretionary margin of North America. The Wrangellia terrane, as part of the Talkeetna superterrane, was obducted onto the continental margin of North America probably during mid-Cretaceous time (Csejtey and others, 1980). The collision of the Talkeetna superterrane with the Yukon-Tanana terrane to the north caused intense deformation and greenschist to amphibolite facies metamorphism of the flysch and turbidite sediments that were deposited in an oceanic arc basin between the converging terranes (Csejtey and others, 1982). The geologic map of the Healy quadrangle (Csejtey and others, 1986), which illustrates the distribution of the different rock types and gives a brief description of each, is the base map for plate 1. Figure 2 is generalized geologic map of the Healy quadrangle and illustrates the distribution of major rock types.

Structure

Major faults in the area have been used to subdivide the Healy quadrangle into as many as 13 separate tectonostratigraphic terranes (Coney and



EXPLANATION

Qs	Surficial deposits (Quaternary)	KJf	Flysch (Cretaceous and Jurassic)
Ts	Sedimentary rocks (Tertiary)	TRs	Calcareous sedimentary rocks (Triassic)
Tc	Cantwell Formation (Tertiary)	TRPs	Wrangellia terrane (Triassic and Paleozoic)
TKg	Granitic rocks (Tertiary and Cretaceous)	MzPz	Chulitna terrane (Mesozoic and Paleozoic)
Km	Melange(?) (Cretaceous*)	Pqs	Pelitic quartz schist (Paleozoic and Precambrian?)

* Age shown is accretionary age

Figure 2. Generalized geologic map of the Healy quadrangle, Alaska. (Modified from Csejtey and others, 1986.)

others, 1980; Jones and others, 1981, 1983; Silberling and Jones, 1984). The McKinley and Hines Creek strands of the Denali fault (Beikman and others, 1977; Beikman, 1978) traverse the entire quadrangle from east to west (fig. 2). Jones and others (1983) used the Hines Creek fault to divide the Yukon-Tanana terrane to the north from the Pingston terrane to the south, and the McKinley fault to divide the Dillinger, McKinley, and Pingston terranes on the north from the Jurassic and Cretaceous flysch and other terranes to the south. The Chulitna thrust and the Broad Pass, Cantwell, and Hurricane faults all trend northeasterly across the southwestern corner of the quadrangle and have been used to define several tectonostratigraphic terranes in this vicinity (Jones and others, 1981, 1983). The Talkeetna thrust trends northeasterly across the southeastern corner of the quadrangle and separates Jurassic and Cretaceous flysch to the north from the Talkeetna superterrane (includes the Wrangellia terrane of Jones and others, 1983) to the south (Csejtey and others, 1986).

Csejtey and others (1982, 1986), on the basis of correlative geologic units and metamorphic isograds on both sides of the McKinley fault, suggest that the McKinley fault is not a tectonostratigraphic terrane boundary in this area. They also define the Hines Creek fault as a dip-slip fault that formed within the Yukon-Tanana terrane. These interpretations, as well as other stratigraphic, structural, and lithologic evidence, have allowed Csejtey and others to distinguish as few as five tectonostratigraphic terranes in addition to the Jurassic and Cretaceous flysch unit (Csejtey and others, 1986).

Rock Units

The Yukon-Tanana terrane exposed chiefly in the northern part of the Healy quadrangle is composed predominantly of quartz-sericite, carbonaceous, and pelitic schists or phyllites, and metavolcanic rocks of Precambrian or Paleozoic age; calcareous sedimentary rocks of Triassic age; and clastic sedimentary and coal-bearing rocks of Tertiary age (Wahrhaftig, 1968, 1970a-d). The oldest rocks in this part of the quadrangle are pelitic quartz sericite and muscovite schists of Precambrian or Paleozoic age that have been previously correlated with the now-abandoned Birch Creek Schist and the overlying Keevy Peak Formation. The name Birch Creek Schist is not used in our report because of uncertainties in the definition of the unit (Csejtey and others, 1986). Stratigraphically above the Keevy Peak Formation is a series of Paleozoic phyllites and schists including the Totatlanika Schist, metasedimentary rocks, metabasalts, felsic metavolcanic rocks, and the informally named Yanert Fork sequence (Csejtey and others, 1986). A thick sequence of highly deformed Triassic marine calcareous sedimentary rocks occurs in scattered outcrops south of the Hines Creek fault. This unit is most predominant in the area of West Fork Glacier and along the upper Wood River in the east-central part of the quadrangle. Tertiary rocks in the Yukon-Tanana terrane are the Cantwell Formation, several coal-bearing units, and the Nenana Gravel. With the exception of small isolated outcrops, these units occur exclusively to the north of the McKinley fault.

Rocks in the southern part of the Healy quadrangle are dominantly Jurassic and Cretaceous flysch, Cretaceous granites, and Tertiary granitic and volcanic rocks. Triassic calcareous sedimentary rocks crop out in several localities. The Wrangellia terrane, south of the Talkeetna thrust, is composed of the Triassic Nikolai Greenstone and older Pennsylvanian to Triassic sequences of metavolcanic and metasedimentary rocks (Csejtey and others, 1986). The Chulitna terrane comprises several distinct lithologic units, from middle Paleozoic to Mesozoic age, consisting of sedimentary, volcanic, and plutonic rocks that have been tectonically juxtaposed (Jones and others, 1981; Csejtey and others, 1986).

Numerous small to medium-sized granitic plutons of Cretaceous or Tertiary age occur throughout the quadrangle, except in the Wrangellia terrane (south of the Talkeetna thrust). Cretaceous plutons are predominantly tonalite, and the Tertiary plutons are mostly granite and granodiorite (Csejtey and others, 1986).

MINERAL DEPOSITS

Two major areas of mineral occurrences in the Healy quadrangle are the Upper Chulitna district in the southwestern corner of the quadrangle and the Valdez Creek district in the southeastern corner of the quadrangle. Berg and Cobb (1967) included both of these areas in the Cook Inlet-Susitna River region.

The Upper Chulitna district extends about 30 mi northeasterly from the southwestern corner of the quadrangle to near Bull River (T. 19 S., R. 10 W.). Mineral deposits in the Upper Chulitna district have been described by Ross (1933a), Hawley and Clark (1968, 1973, 1974), and Hawley and others (1969) as epigenetic vein (Colorado Creek), disseminated (Copper King), breccia-pipe (Golden Zone), and contact metamorphic deposits containing gold, silver, copper, lead, zinc, and arsenic. The Golden Zone mine, the largest producer in the quadrangle, was developed in a breccia zone above a quartz diorite porphyry and produced 1,600 oz (ounce) Au, 9,000 oz Ag, 21 tons Cu, and 1.5 tons Zn (Hawley and Clark, 1974). Minor concentrations of chromium and nickel occur in ultramafic rocks in the district. A tin-bearing greisen in a small granitic stock in Ohio Creek (T. 20 S., R. 12 W.) was described by Hawley and Clark (1974). Tin occurrences associated with the

McKinley sequence of highly evolved 55–60 Ma granites (Reed and Lanphere, 1973; Lanphere and Reed, 1985) were described by Reed and others (1978) in the Talkeetna quadrangle, adjacent to the southwest corner of the Healy quadrangle.

The Valdez Creek mining district (Ross, 1933b; Tuck, 1938; Kaufman, 1964; Smith, 1981) comprises a group of placer gold and lode copper and gold deposits in the Clearwater Mountains in the southeastern corner of the Healy quadrangle. The Denali stratiform sulfide deposit, within the Valdez Creek mining district, contains chalcopyrite, pyrite, and sphalerite and has been described by Stevens (1972) and Seraphim (1975).

Clark and Cobb (1972), MacKevett and Holloway (1977), and Cobb (1978), reported numerous other mineral deposits in the Healy quadrangle including the following: placer gold deposits east of Suntrana (T. 12 S., R. 6 W.) and east from Jumbo Dome (T. 11 S., R. 6 W.) to Moose Creek along the northern boundary of the quadrangle; placer gold deposits in the northeast corner of the quadrangle; lode gold and base-metal deposits between Wood River and West Fork Little Delta River; base- and precious-metal occurrences in the Reindeer Hills area; and a gold-antimony occurrence about 6 mi northeast of Honolulu (Hawley and others, 1968).

The Yukon-Tanana terrane in the northeastern quarter of the Healy quadrangle contains several occurrences of volcanogenic massive sulfides not previously described. One of these, the Red Mountain deposit (also called the Dry Creek deposit), is a rhyolite-hosted volcanogenic massive sulfide deposit in the Mississippian(?) Mystic Creek Member of the Totatlanika Schist. Several companies have examined the Red Mountain deposit, but no ore has been produced.

ANALYTICAL METHODS

The stream-sediment and heavy-mineral concentrate samples were analyzed for 31 elements using a semiquantitative, direct-current arc emission spectrographic method (Grimes and Marranzino, 1968). The elements analyzed and their lower limits of determination are listed in table 1. Spectrographic results were obtained by visual comparison of spectra derived from the sample against spectra obtained from standards made from pure oxides and carbonates. Standard concentrations are geometrically spaced over any given order of magnitude of concentration as follows: 100, 50, 20, 10, and so forth. Samples whose concentrations are estimated to fall between those values are assigned values of 70, 30, 15, and so forth. The precision of the analytical method is approximately plus or minus one reporting interval at the 83-percent confidence level and plus or minus two reporting intervals at the 96 percent confidence level (Motooka and Grimes, 1976).

DISTRIBUTION AND INTERPRETATION OF GEOCHEMICAL ANOMALIES

All analytical data were entered into the USGS RASS (U.S. Geological Survey Rock Analysis Storage System) digital storage system for manipulation with the USGS STATPAC (statistical package) programs (VanTrump and Miesch, 1977). The raw, unprocessed data were reported by O'Leary and others (1984). Localities at which samples contained anomalous concentrations of selected elements, determined by univariate statistical analysis, were illustrated on multielement plots of the data for stream-sediment (King and others, 1989) and heavy-mineral-concentrate samples (Light and others, 1989).

The associations of anomalously high concentrations of elements within the geochemical data set can be used to distinguish areas of different lithology or chemical composition or to define the most favorable areas for mineral occurrences. In addition, where tectonostratigraphic terranes are chemically distinct, geochemical associations and data-processing techniques, such as factor analysis, can be used to help define a unique geochemical signature for these terranes (Light, 1985).

Because stream-sediment and nonmagnetic heavy-mineral concentrate samples are integrated drainage-basin samples that commonly represent a varying degree of input from more than one rock unit or lithology, the geochemical signature tends to be more subdued than for a data set based solely on rock samples. Nevertheless, several rock formations or groups of formations in the Healy quadrangle can be distinguished by the unique element associations found in stream sediments and heavy-mineral concentrates derived from these units. In addition, areas of known mineral occurrences are readily discernible, and the distribution of samples containing elements associated with mineral occurrences indicates the most favorable areas for the occurrence of additional mineral deposits. The concentration and associations of selected elements that reflect mineralization in the Healy quadrangle are shown by King and others (1989) for stream-sediment samples and by Light and others (1989) for nonmagnetic heavy-mineral concentrate samples. Tripp and others (1989) show the distribution of ore-related minerals in the nonmagnetic fraction of heavy-mineral concentrate samples. A mineral resource assessment of the Healy quadrangle has been reported by Cox and others (1989).

For the purpose of this report, because no geochemical bedrock data are available to define background values within the various rock types, the 95th percentile of the analytical data was chosen as the threshold to define the lower limit of an anomaly. Because the data are reported in scale with six-steps per

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Table 1. Limits of determination for the spectrographic analysis of nonmagnetic heavy-mineral concentrates and stream sediments

[Fe, Mg, Ca, and Ti in percent; all others in parts per million]

Element	Lower determination limit		Upper determination limit	
	Concentrates	Sediments	Concentrates	Sediments
Iron (Fe)	0.1	0.05	50	20
Magnesium (Mg)	.05	.02	50	10
Calcium (Ca)	.1	.05	50	20
Titanium (Ti)	.005	.002	2	1
Manganese (Mn)	20	10	10,000	5,000
Silver (Ag)	1	0.5	10,000	5,000
Arsenic (As)	500	200	20,000	10,000
Gold (Au)	20	10	1,000	500
Boron (B)	20	10	5,000	2,000
Barium (Ba)	50	20	10,000	5,000
Beryllium (Be)	2	1	2,000	1,000
Bismuth (Bi)	20	10	2,000	1,000
Cadmium (Cd)	50	20	1,000	500
Cobalt (Co)	10	5	5,000	2,000
Chromium (Cr)	20	10	10,000	5,000
Copper (Cu)	10	5	50,000	20,000
Lanthanum (La)	50	20	2,000	1,000
Molybdenum (Mo)	10	5	5,000	2,000
Niobium (Nb)	50	20	5,000	2,000
Nickel (Ni)	10	5	10,000	5,000
Lead (Pb)	20	10	50,000	20,000
Antimony (Sb)	200	100	20,000	10,000
Scandium (Sc)	10	5	200	100
Tin (Sn)	20	10	2,000	1,000
Strontium (Sr)	200	100	10,000	5,000
Vanadium (V)	20	10	20,000	10,000
Tungsten (W)	100	50	20,000	10,000
Yttrium (Y)	20	10	5,000	2,000
Zinc (Zn)	500	200	20,000	10,000
Zirconium (Zr)	20	10	2,000	1,000
Thorium (Th)	200	100	5,000	2,000

order of magnitude, the 95th percentile was commonly enclosed in a group of samples with the same value. Where this occurred, the threshold was determined to be at that value and included all samples within that group or at the next higher value. The thresholds for determining anomalous values range from 91.8 to 96.8 percentile. Histograms showing the frequency distributions of analytical data are given by King and others (1989) and Light and others (1989) for stream sediments and heavy-mineral concentrates, respectively.

In the Healy quadrangle, concentrations of elements, ore-related minerals, or associations of elements and (or) minerals were used to define 17 separate geochemically anomalous areas. These anomalous areas, the distribution of sample localities, and the geology of the Healy quadrangle are shown on plate 1. The drainage basins sampled and the elements that were determined to have anomalously high concentrations within those basins are illustrated on plate 2 for stream-sediment samples and on plate 3 for heavy-mineral-concentrate samples. The distribution of elements by sample media has been reported by King and others (1989) for the stream sediments and by Light and others (1989) for the heavy-mineral concentrates. A summary of data for geochemically anomalous areas is given in table 2. A list of elements that were determined to have anomalous concentrations at each sample locality and for each sample media is given in the appendix.

Highly evolved siliceous granites of the 55–60 Ma McKinley sequence (Reed and Lanphere, 1973) have

9	Upper Jack River.	Ag, Au, (Cd), (Pb), (Sn).	Ag, (Au), (Bi), Cd, (Cu), Mo, (Sb), (Sn), (W), Zn.	ars, cass, (cinn), cpy, flu, (gal), gold, sch, sph.	Tg, Tv, KJf.	Jurassic and Cretaceous flysch.	Sn-greisen, Sn-vein, porphyry Cu/Mo, polymetallic vein Sb-vein, placer gold.	None known.
10	Upper Revine Creek.	Ag, As, B, Ba, Co, Cu, Mo, W, Zn.	Mo, (Sb), (Sn), W, (Zn).	ars, cass, cinn, cpy, (gal), pow, sch, sph.	Tg, Tc, KJf, TRdb, Pzy.	Jurassic and Cretaceous flysch.	Porphyry Cu/Mo, Sn-greisen, Sn-vein skarn.	None known.
11	Valdez Creek.	(Ag), Au, (Fe)	(Ag), (Au), (Bi), (Mo), (W).	ars, cpy, (gal), gold, sch.	Tg, Kg, Kv KJf, Jgb.	Jurassic and Cretaceous flysch.	Metamorphic gold. Placer gold	Timberline Creek (Smith, 1981). Valdez Creek (Tuck, 1938).
12	West Fork Glacier.	Ag, (As), Au, Ba, (Co), (Cr), Mo.	(Ag), (Au).........	ars, cpy, (gal), (gold), sch.	Tg(?), Kg, TRcs.	Yukon-Tanana terrane.	Skarn, porphyry Cu/Mo, polymetallic vein, placer gold. Volcanogenic massive sulfide (?)	None known. Unnamed occurrence (MacKevett and Holloway, 1977).
13	West McKinley fault.	As, (Au), (B), (Cr), (Pb), (Sn), (Zn).	Ag, (As), (Au), Cd, Co, Cr, Fe, Pb, Ni, Sb, (Sn), Zn.	ars, (cass), (cinn), cpy, gal, (gold), (sch), sph, (stib).	Tg, Tc, di, Km, KJf, Pzd.	Jurassic and Cretaceous flysch and tectonic melange.	Sn-greisen, Sn-vein, polymetallic vein, placer gold.	None known.
14	Wrangellia terrane.	(As), Au, Co, Cr, Cu, Fe, Ni.	(Au), (Cu).........	(ars), (cinn), cpy, sch.	JKs, Trm, Ps, IPv.	Wrangellia terrane of Talkeetna superterrane.	Volcanogenic massive sulfide. Placer gold.	Denali (Stevens, 1972; Seraphim, 1975). None known.
15	Wyoming Hills.	(Ag), (As), Ba, Pb, Zn.		sch..................	Tv, Tg........	Yukon-Tanana terrane.	Polymetallic vein.	None known.
16	Yanert Glacier.	Ag, (Ba), (Cu), Mo, W.	(As), Cu, (Mo).....	ars, cpy, (gal), sch, sph.	Kg, KJf, TRs, Pzy.	Yukon-Tanana terrane.	Porphyry Cu/Mo polymetallic vein.	None known.
17	Yukon-Tanana.	Ag, Au, B, Ba, Co, (Mo), Pb, (W), Zn.	Ag, As, (Au), (Bi), Co, (Cu), Fe, Mo, Ni, Pb, (Sb), W.	ars, cpy, gal, gold, pow, sch, sph.	Kg, Pzmf, Pzmb, Pzms, Pzts, pqs.	Yukon-Tanana terrane.	Volcanogenic massive sulfide Polymetallic vein. Placer gold..........	Red Mountain (MacKevett and Holloway, 1977). Glory Creek (Clark and Cobb, 1972). Dry Creek (Capps, 1912).

[1]Mineral abbreviations: ars, arsenopyrite ($FeAsS$). cass, cassiterite (SnO_2). cinn, cinnabar (HgS). cpy, chalcopyrite ($CuFeS_2$). flu, fluorite (CaF_2). gal, galena (PbS). pow, powellite ($Ca(Mo,W)O_4$). sch, scheelite ($CaWO_4$). sph, sphalerite (ZnS). stib, stibnite (Sb_2S_3).

[2]See plate 1 for explanation of geologic units.

been described in the Talkeetna quadrangle, adjacent to the southwest corner of the Healy quadrangle (Reed and others, 1978). Tin-bearing greisens associated with McKinley sequence granites occur in the Ohio Creek area (T. 20 S., R. 12 W.), in the southwest corner of the Healy-quadrangle (Hawley and Clark, 1974), and in the Coal Creek area, about 15 mi (25 km) southeast of the Ohio Creek occurrence (Bundtzen and Eakins, 1984). Numerous granitic intrusions of unknown age occur in a northeasterly trend across much of the Healy quadrangle, from the Chulitna district in the southwest to Nenana Mountain (T. 16 S., R. 2 W.), and possibly as far as Glory Creek (T. 12 S., R. 1 E.) on the northeast. The concentration, distribution, and association of base and precious metals and ore-related minerals in reconnaissance drainage-basin samples suggest that at least some of these granitic plutons may be related to the McKinley sequence and define a broad northeasterly trending belt of favorable area for tin-bearing greisen mineralization in the southwestern part of the quadrangle.

Yukon-Tanana Terrane

From Dora Peak (T. 12–13 S., R. 6 W.) eastward to the boundary of the Healy quadrangle, a group of metamorphosed, Paleozoic marine, volcaniclastic and clastic schists, argillites, and phyllites include the Totatlanika Schist along the northern boundary of the quadrangle, a Precambrian or Paleozoic pelitic quartz-sericite schist (the Birch Creek Schist of former usage) south of the Totatlanika, and a Paleozoic metabasalt and metasedimentary rocks extending southward to the Hines Creek fault. At least six volcanogenic massive sulfide occurrences associated with pelitic schists and felsic metavolcanic rocks have been reported in the area north of the Hines Creek fault and in the eastern one-third of the quadrangle (Church and others, 1986, 1987). Increased concentrations of Fe, Co, Ni, and Cr suggest that the rocks become more mafic in the vicinity of Dora Peak. The occurrence of anomalously high concentrations of base and precious metals in sediment and concentrate samples (King and others, 1989; Light and others, 1989), and the distribution of galena, sphalerite, and arsenopyrite in heavy-mineral concentrate samples (Tripp and others, 1989) from the northern Healy quadrangle indicate that volcanogenic sulfide mineralization is favorable throughout the Yukon-Tanana terrane in the eastern half of the Healy quadrangle.

In the vicinity of Dora Peak (T. 12–13 S., R. 5–6 W.) locally disseminated pyrite, arsenopyrite, chalcopyrite, galena, and sphalerite in quartz-sericite schist are probably the source of scattered Ag, As, Au, Cu, Pb, and Zn anomalies. Local mafic hypabyssal and subvolcanic rocks that intrude the schist are reflected in high Fe, Co, and Ni concentrations. Small intrusive bodies and the greenschist and lower grade facies metamorphism that produced the pelitic schists may have caused some local remobilization and concentration of the base and precious metals. However, the weakly disseminated sulfides were probably syngenetic with the deposition of marine clastic and volcaniclastic sediments, and volcanogenic massive sulfide deposits, similar to those in the northeastern part of the quadrangle, may be present in these units.

To the north of Keevy Peak (T. 11 S., R. 3 W.), scattered anomalous concentrations of Mo and Zn occur along a northwest-trending fault from Wood River to Moose Creek. A similar geochemical signature occurs in Last Chance Creek near the contact between the Keevy Peak Formation and the Totatlanika Schist (T. 11 S., R. 3 W.). This element association may represent either hydrothermal mineralization along the Moose Creek fault or syngenetic concentrations in the volcaniclastic rocks of the Totatlanika Schist that have been remobilized by metamorphism.

The area drained by the Wood River and West Fork Little Delta River in the northeast part of the Healy quadrangle (T. 11–13 S., R. 2 W.-R. 3 E.) has anomalous concentrations of base and precious metals at numerous localities. Disseminated pyrite is locally abundant in the Precambrian(?) quartz-sericite pelitic schist (the Birch Creek Schist of former usage) throughout the eastern half of the Healy quadrangle. Local concentrations of disseminated pyrite and arsenopyrite with minor galena and sphalerite were found in outcrops on the north flank of Anderson Mountain (T. 13 S., R. 2 W.), in a tributary to Kansas Creek (T. 12 S., R. 1 W.), and near the head of Healy Creek (T. 13 S., R. 4 W.). In addition, gold, scheelite, and powellite were observed in concentrate samples from these drainages. The widespread occurrence of disseminated sulfides in pelitic schist, which may have been derived from submarine volcaniclastic deposits, suggests the possibility for volcanogenic massive sulfide deposits in this area. Alternatively, if the parent sediments were deposited in a euxinic environment, the sulfides may have been organically derived and subsequently remobilized during metamorphism.

A group of samples from drainages on Copper Creek (T. 12 S., R. 2 W.), Kansas Creek (T. 12 S., R. 1 W.), and Glory Creek (T. 12 S., R. 1 E.) contained anomalously high values for several base and precious metals. This area is underlain by a Precambrian or Paleozoic pelitic schist previously correlated with the Birch Creek Schist. Clark and Cobb (1972) list a lode gold and an Sb-Au-Pb-Zn occurrence in Kansas Creek and an Sb-Au-Pb-Ag-Zn deposit in Glory Creek. The Glory Creek deposit consists of several quartz veins containing stibnite, galena, sphalerite, arsenopyrite, chalcopyrite, scheelite, powellite, and gold, plus high concentrations of Bi and Cd. Stream-sediment and heavy-mineral concentrate samples from Kansas Creek, Copper Creek, and their tributaries contain anomalously high concentrations of Ag, As, Au, Bi, Mo, Pb, Sb, W, and Zn. Mineralization in the area from Copper Creek to Glory Creek is spatially related to a well-exposed fault that follows the Kansas Creek and Glory Creek drainages and possibly extends across the Wood River and along the Copper Creek drainage. Church and others (1986, 1987) reported that Pb-isotope data for galenas from the Glory Creek deposit were consistent with Pb-isotope data for galenas from the Cretaceous plutons. This consistency suggests that base and precious metals in veins along the Copper Creek-Glory Creek trend were probably either derived from, or remobilized by, the emplacement of nearby Cretaceous granitic rocks.

Six samples taken from the drainages of Buchanan Creek and its tributaries (T. 13 S., R. 2–4 E.) contained anomalous concentrations of Mo, locally associated with Ag, Au, Pb, and W. These metals were probably emplaced by hydrothermal fluids emanating from nearby Cretaceous granitic intrusions and may indicate either vein or porphyry mineralization.

Big Grizzly Creek Area

The Big Grizzly Creek area (T. 13–14 S., R. 2 E.-R. 2 W.) along the south side of the Hines Creek fault comprises an area of Paleozoic pelitic schists and Triassic calcareous sedimentary rocks intruded by Cretaceous granite. Cobb (1978, 1984) reported a placer gold occurrence to the west in Grizzly Creek. Arsenopyrite, barite, chalcopyrite, galena, scheelite, and sphalerite were observed in mineralogical samples, and spectrographic analyses showed scattered anomalously high concentrations of Ag, Mo, Pb, and Zn. These associations may indicate the presence of volcanogenic massive sulfides in the schist or vein and porphyry-type deposits related to the emplacement of granitic plutons. Where hydrothermal fluids penetrated calcareous sediments, or near the intrusive rocks, replacement and skarn-type deposits may have formed. Mineral occurrences peripheral to the Cretaceous intrusions could have been derived from the intrusive rocks or remobilized from the host rocks.

Tertiary Nenana Gravel and Coal-Bearing Rocks

The Tertiary Nenana Gravel and coal-bearing rocks crop out along the northern boundary of the Healy quadrangle. Several scattered anomalously high gold values in the Nenana Gravel, especially in the vicinity of Lignite Creek (T. 11 S., R. 6–7 W.), Walker Dome (T. 11 S., R. 7 W.), and Newman Creek (T. 11 S., R. 2 E), suggest the possibility for local placer gold deposits. Cassiterite and scheelite also occur locally and represent resistant mineral phases present in the source rocks from which these sedimentary materials were derived. Capps (1912) reported that placer gold deposits in the northern Healy and southern Fairbanks quadrangles are spatially related to drainages that cut areas underlain by the Tertiary Nenana Gravel, and that reworked gold from that unit was probably the source of these placer deposits. The distribution of gold and cassiterite (Tripp and others, 1989) in Tertiary units in the northeastern and north-central parts of the Healy quadrangle indicates that the Tertiary coal-bearing rocks as well as the Nenana Gravel may be the source for both these resistant minerals.

Chulitna District

The Chulitna district includes the Chulitna tectonostratigraphic terrane and the Ohio Creek tin-bearing greisen occurrence just west of the Cantwell fault. The Chulitna terrane lies in the southwestern part of the Healy quadrangle, northwest of the Chulitna River, and is a composite of several rock types including mafic and ultramafic rocks, basalt, limestone, and red-bed sandstones all in thrust contact with each other (Jones and others, 1981). The Chulitna terrane is interpreted to be a composite terrane tectonically emplaced during the accretion of the Wrangellia terrane to North America (Csejtey and others, 1982).

The geochemistry of samples from the Chulitna terrane reflects the unique lithology of the area and the occurrence of numerous mineral deposits. Mineral deposits in the Chulitna terrane consist of small chromium and nickel occurrences in ultramafic rocks, gold, copper, and arsenic in vein, porphyry, and contact metamorphic deposits, and placer gold deposits (Hawley and Clark, 1974). Most mineral deposits in the Chulitna terrane are associated with small Tertiary intrusive plugs and stocks. Because of the size of the Chulitna terrane and the abundance of mineral deposits, the entire terrane is considered to be an area of anomalously high concentrations of base and precious metals.

Both sediment and concentrate samples from the Chulitna terrane are anomalously high in Fe, Mg, Ni, Co, Cr, Cu, Au, Ag, As, and Ba. In addition, stream-sediment samples were anomalously high in B and Pb, and concentrate samples were anomalously high in Be, Bi, Mn, Sb, W, and Zn. Concentrate samples contained abundant arsenopyrite, chalcopyrite, galena, sphalerite, cassiterite, and scheelite, and local concentrations of gold, stibnite, and cinnabar.

The Ohio Creek tin-bearing greisen (T. 20 S., R. 12–13 W.) to the west of the Chulitna terrane is indicated by sediment and concentrate samples containing anomalously high concentrations of Sn and W. In addition, the concentrate samples contain abundant Ag, As, Au, Ba, Bi, and Sb. These element associations and the presence of arsenopyrite, cassiterite, chalcopyrite, galena, gold, scheelite, sphalerite, and stibnite in concentrate samples reflect the small tin-bearing greisen. Additional tin-bearing greisens may exist in this area in cupolas at the top of the Tertiary granitic intrusions.

Honolulu Area

The Honolulu area is underlain by the Jurassic and Cretaceous flysch with several Tertiary granitic intrusions (Csejtey and others, 1986). This area lies east of the Chulitna River, south of the East Fork of the Chulitna River, and west of Crooked Creek (T. 20–21 S., R. 8 W.) in the southwestern Healy quadrangle. Capps (1919) and Hawley and others (1968) reported Sb and Au in quartz veins near the head of Antimony Creek (T. 21 S., R. 10 W.).

Analyses of samples from the Honolulu area show high concentrations of Ag, Au, Cu, Pb, and Sn in both sediment and concentrate samples. Concentrate samples also contain anomalously high Bi, Mo, Sb, and W, plus visible arsenopyrite, cassiterite, chalcopyrite, fluorite, gold, powellite, scheelite, sphalerite, and minor galena. The association of base and precious metals suggests the possibility for several mineral deposit types in addition to Au-Sb veins. The occurrence of Ag, Cu, Sn, Sb, W, and Bi in stream drainages near Tertiary granitic intrusions suggests the possibility for Sn-bearing greisen deposits similar to the Ohio Creek deposit. The presence of Ag, Au, Cu, Mo, and Pb with fluorite may reflect hydrothermal vein or porphyry type deposits. Where carbonate units within the Jurassic and Cretaceous flysch have been intruded, skarn or replacement-type deposits may also exist.

Upper Jack River Area

Tertiary felsic volcanic rocks crop out in the upper Jack River area from near Caribou Pass (T. 19 S., R. 7 W.) to the south for 10 mi (16 km), and are as much as 15 mi (24 km) wide. This area contains scattered high values for a large suite of base and precious metals. Silver, As, Be, Bi, Cu, Mo, Pb, Sb, Sn, W, and Zn occur in various combinations throughout the area. Arsenopyrite, cassiterite, chalcopyrite, fluorite, gold, scheelite, and sphalerite plus minor cinnabar and galena were found in heavy-mineral concentrates. No mineral occurrences or deposits have been reported in this area, but this large suite of elements suggests the possibility for several types of deposits. The Ag-Cu-Sn-Sb-W-Bi suite may indicate the presence of tin-bearing greisens similar to those in the Ohio Creek drainage, and the Ag, As, Cd, Cu, Mo, Pb, and Zn association could reflect the presence of a wide variety of epigenetic hydrothermal mineral deposit types, including porphyry-related deposits and polymetallic veins.

Valdez Creek Area

North of the Talkeetna thrust and south of Monahan Flat, several broad areas of Jurassic and Cretaceous flysch have been intruded by both Cretaceous and Tertiary granitic rocks. Placer gold has been produced from several localities in the Valdez Creek area (T. 19–20 S., R. 2–3 E.) in the northwestern Clearwater Mountains (Tuck, 1938; Smith, 1981). Gold, Ag, W, Bi, and minor Mo and Cu occur in some stream-sediment or heavy-mineral-concentrate samples from the Valdez Creek and Gold Creek-Wickersham Creek (T. 20–21 S., R. 1–2 W.) areas. Arsenopyrite, chalcopyrite, gold, scheelite, and minor galena occur in scattered heavy-mineral concentrate samples. Smith (1981) reported gold-bearing veins in both the Jurassic and Cretaceous flysch and the Cretaceous granitic rocks in the Valdez Creek area. The metals in both the Valdez Creek area and in the Gold Creek-Wickersham Creek area were probably deposited by late stage hydrothermal fluids associated with the emplacement of the Cretaceous plutons.

In the Gold-Wickersham Creeks area, at localities 299–308 (T. 20–22 S., R. 1 E.-R. 3 W.), a central zone of Mo and Au appears to be partially bounded by a zone of Mn with scattered W, Bi, and (or) B (plates 2 and 3). These anomalies may indicate a low-F Mo porphyry system or associated vein mineralization related to the intrusion of Tertiary and Cretaceous granites to the north of Gold Creek.

Between the Susitna Glacier and the East Fork Susitna River (T. 17 S., R. 3–4 E.), Au was found in three samples near the edge of the quadrangle. The Au was probably derived from late-stage veins cutting the Cretaceous granitic rocks in this area.

Wrangellia Terrane

The Wrangellia terrane is a tectonically emplaced group of allochthonous mafic rocks lying to the south of the Talkeetna thrust in the southeastern corner of the Healy quadrangle. Several localities containing Cu in shear zones and stratabound deposits in the Triassic Nikolai Greenstone have been described by Cobb (1978).

The Denali stratabound copper deposit (T. 20 S., R. 3 E.) has been described by Stevens (1972) and Seraphim (1975). High values of Cu (chalcopyrite) and isolated occurrences of Au, Ag, arsenopyrite, cinnabar, and scheelite suggest that these deposits represent the dominant type of mineralization in this area. Small placer Au deposits may form downstream from these mineralized areas.

Edmonds Creek

Edmonds Creek (T. 18 S., R. 5 W.) drains an area underlain by Triassic calcareous sedimentary rocks and Jurassic and Cretaceous flysch that has been intruded by Tertiary felsic rocks. Stream-sediment samples from this area contained anomalously high concentrations of Zn. Heavy-mineral-concentrate samples were anomalously high in Sn and also contained arsenopyrite, cassiterite, chalcopyrite, galena, scheelite, and minor gold and Bi. This element and mineral association could reflect a buried tin-bearing greisen, polymetallic veins, or skarn deposits.

Reindeer Hills-Pyramid Peak Area

The Reindeer Hills-Pyramid Peak (T. 17 S., R. 4–7 W.) area is underlain by tectonic melange lithologically similar to the Jurassic and Cretaceous flysch (Csejtey and others, 1986). Arsenopyrite, cassiterite, gold, scheelite, and minor galena were observed in heavy-mineral concentrates, and spectrographic analyses revealed anomalously high Ag, As, Au, Bi, Mo, Sb, Sn, and W in samples along the south flank of Reindeer Hills. The similarity of the distribution of trace elements and minerals to that in the Ohio Creek area suggests the possibility of buried tin-bearing greisen deposits. Small outcrops of Tertiary granitic rocks in Reindeer Hills support the interpretation that the tectonic melange unit is, at least in part, underlain by rocks similar to those containing greisen deposits in the Ohio Creek area.

Anomalous trace-element concentrations of Ag, Au, Bi, Cd, Sn, and Zn, plus scattered occurrences of arsenopyrite, cassiterite, fluorite, galena and gold in concentrate samples derived from streams draining areas of Tertiary granite along the east flank of Pyramid Peak may indicate the presence of a tin-bearing greisen or vein-type mineralization in this area.

Upper Revine Creek

Samples from east of Panorama Mountain, near the headwaters of Revine Creek (T. 16 S., R. 5 W.), contain scattered high values of Ag, As, Bi, Cu, Mo, Sn, W, and Zn in arsenopyrite, cassiterite, chalcopyrite, cinnabar, galena, powellite, scheelite, and sphalerite. Most of these samples came from streams draining Cretaceous and Jurassic flysch and downstream from Tertiary granitic rocks. Geochemical anomalies in the upper Revine Creek area are subtly zoned from generally high concentrations of Cu, Mo, and W in the central part of the area, at samples 562–564, outward to a relatively more dominant As, B, Pb, and Zn assemblage. Although no mineral occurrences are known in this area, the observed anomalies are similar to those from the area south of Caribou Pass. Types of deposits that may occur in the upper Revine Creek area include porphyry and porphyry-related deposits, polymetallic veins, and tin-bearing greisen.

Western McKinley Fault Area

The McKinley fault to the west of the Nenana River is bounded on the north by a Cretaceous tectonic melange and a metamorphosed Paleozoic turbidite sequence and on the south by Jurassic and Cretaceous flysch and Tertiary granitic rocks (Csejtey and others, 1986). The occurrence of arsenopyrite, cassiterite, chalcopyrite, cinnabar, galena, gold, scheelite, sphalerite, and stibnite, and anomalously high concentrations of Ag, As, Cd, Pb, Sb, and Zn in samples from this area probably reflect the presence of mineralized hydrothermal veins related to the emplacement of the Tertiary granitic plutons.

Polychrome Glacier Area

Scattered occurrences of arsenopyrite, cassiterite, chalcopyrite, cinnabar, fluorite, galena, and sphalerite (Tripp and others, 1989) from Polychrome Glacier (T. 17 S., R. 12 W.) northeastward toward Double Mountain (T. 15 S., R. 10 W.) are probably related to outcrops of Tertiary volcanic rocks. Minor amounts of As, Cd, Fe, Pb, Sn, and Zn also occur in sediment and concentrate samples from this area. These mineral and element associations may indicate the presence of polymetallic epithermal vein-type deposits in this area.

Nenana Mountain Area

Along the west flank of Nenana Mountain (T. 16 S., R. 1 W.), in a tributary to Yanert Fork, arsenopyrite, cassiterite, chalcopyrite, galena, gold, scheelite, and sphalerite, plus a large suite of anomalous trace elements occur in concentrate samples derived from near the contact of Tertiary granitic rocks and the Jurassic and

Cretaceous flysch. The association of samples containing Ag, As, Au, Bi, Cd, Cu, Mo, Pb, Sb, Sn, Th, W, or Zn indicates the possibility of hydrothermal mineralization, probably related to the intrusion of the granite. The trace-element assemblage of Sn, Sb, Bi, W, Ag, and Au may reflect the presence of a tin-bearing greisen. Epithermal polymetallic veins, skarn deposits, or a porphyry system may also occur in this area.

West Fork Glacier Area

The area around lower West Fork Glacier (T. 17 S., R. 1 E.) is underlain by Triassic calcareous sedimentary rocks intruded by Cretaceous granitic rocks and numerous diabase dikes and sills (Csejtey and others, 1986). Silver, As, Au, B, Ba, Cu, Mo, Pb, and W anomalies, and isolated occurrences of arsenopyrite, chalcopyrite, galena, gold, and scheelite scattered through this area, suggests the presence of local skarns in limestones or polymetallic veins near Cretaceous intrusive rocks. Arsenopyrite, chalcopyrite, galena, and scheelite occur along the flanks of West Fork and Susitna Glaciers eastward to the edge of the Healy quadrangle, and similar mineral occurrences probably continue into the adjacent Mt. Hayes quadrangle.

Yanert Glacier Area

The Devonian Yanert Fork sequence and Triassic calcareous sedimentary rocks have been intruded by Cretaceous granitic rocks in the area of Yanert Glacier (Csejtey and others, 1986). Samples from part of this area (T. 15 S., R. 1–2 E.) contain arsenopyrite, chalcopyrite, galena, scheelite, and sphalerite, and were anomalously high in Ag, As, Au, Bi, Cd, Cu, Mo, Pb, Sb, and W. No mineral deposits have been reported in this area, but the levels of Cu, Mo, Au, Ag, and Ba at localities 217–225 suggest a possibility for a buried Cu-Mo porphyry system, hydrothermal polymetallic veins, or contact replacement deposits.

Wyoming Hills

In the Wyoming Hills area (T. 14 S., R. 12–13 W.), isolated occurrences of scheelite plus Ag, Au, Ba, Mo, Pb, and Zn in sediment samples are related to the distribution of Tertiary felsic granitic and volcanic rocks and may reflect buried deposits formed by hydrothermal mineralization.

FACTOR ANALYSIS

R-mode factor analysis (Koch and Link, 1971) with varimax rotation was used to define geochemical associations in the data. This type of factor analysis is a mathematical transformation that groups similarly behaving elements into factors (groups) based on their correlation coefficients. Factor analysis cannot be run on data sets containing qualified values (detected but greater than or less than the determination limit, or not detected). Therefore, all values qualified with a "G" were given a value one step greater than the upper determination limit, and values qualified with an "L" were given a value one step below the lower determination limit. Values qualified with an "N" were given a value three steps below the lower determination limit.

Rigorous statistical treatment of the data set only allows replacement of data when the detection ratio (number of unqualified values divided by number of analyses) is greater than 0.80. Or, in other words, less than 20 percent of the values for a particular variable are qualified (Miesch, 1976). However, many of the ore-related trace elements occur in determinable concentrations in much less than 80 percent of the samples, and most of these elements have been included in this analysis. The stream-sediment data set had detection ratios less than 0.20 for As, Bi, Cd, Nb, Sb, Sn, W, and Th. Atomic-absorption determinations for As, Cd, and Sb were only available for about 100 samples collected during the 1982 field season. All these elements were deleted from the data set before factor analysis. Although Au had a detection ratio of only 0.10, Au data were retained in the data set because they loaded most strongly into a separate factor and were determined to have a minor effect on the other factors. To define the association of Au in Au-bearing samples, the samples containing Au concentrations above the lower limit of determination were compiled into separate data sets for sediments (100 values) and concentrates (60 values). Elements in these data sets with detection ratio less than 0.4 were deleted, and the remaining data were reduced by *R*-mode factor analysis using varimax rotation. Output from this program indicates a strong association for Au with Ag, Pb, and Sn for the concentrate samples, but no strong association for Au in the sediment samples.

Because of the incorporation of variables containing less than 80 percent unqualified values, there may be some potential of an induced correlation. Comparison of results from this factor analysis with interpretations where variables containing more than 20 percent qualified values were not used (Light, 1985), and comparison with the distribution of ore-related minerals and anomalously high values in the data sets indicate that this approach is useful for regional interpretations.

The goal of factor analysis is to reduce the data to a few factors or groups of elements that can be used to differentiate the characteristic geochemical signatures or distinct trace-element associations specifically attributable to lithology from those reflecting mineral occurrences. Because drainage basins commonly comprise several lithologies, and rock samples were not available to define the background contribution for each lithology, the data were not divided into subsets. The data were treated as one large data set and were log-transformed before factor analysis. Log transformation of the data was done to make the distribution of the data more symmetrical and to reduce the difference between the variance and the mean.

A 7-factor model was chosen as the geologically most meaningful solution for the reconnaissance geochemical data. These 7 factors all have eigenvalues greater than one; they explain 67 percent of the variance in the stream-sediment data and 62 percent of the variance in the heavy-mineral-concentrate data. Table 3 lists the significant factors derived from *R*-mode factor analysis of the stream-sediment and nonmagnetic heavy-mineral-concentrate data. These factors reflect the distribution and associations of elements related to both lithology and mineralization. Comparison of elements loading strongly into the various factors for sediments and concentrates allows some discrimination between the effects of lithology and mineralization. Removal of the magnetic fractions from the heavy-mineral concentrates means that the remaining metal-bearing minerals should enhance the effects of mineralization. The generalized distribution of major rock types in the Healy quadrangle (fig. 2) is used as a base for plots of factor scores. Plots of sample localities greater than the 90th percentile of scores determined by *R*-mode factor analysis for the data set are shown in figures 3 to 16.

Table 3. Varimax rotation factor loadings for stream-sediment (S) and heavy-mineral concentrate (C) data

[Leaders (---) indicate loadings less than 0.40; aa, atomic absorption analysis; all other analyses by semiquantitative emission spectrography; NA, not applicable (element not used in factor analysis)]

Factor.....	1S	2S	3S	4S	5S	6S	7S	Detection ratio (S)	1C	2C	3C	4C	5C	6C	7C	Detection ratio (C)
Fe.......	.71	---	---	---	---	---	---	1.0	.88	---	---	---	---	---	---	0.94
Mg.......	.61	---	---	---	---	.52	---	1.0	---	---	.88	---	---	---	---	.98
Ca.......	---	---	---	---	---	.85	---	1.0	---	---	.71	---	---	---	---	1.0
Ti.......	.44	---	---	---	---	---	---	.95	---	.75	---	---	---	---	---	.23
Mn.......	.49	---	---	---	---	.42	---	1.0	---	---	.82	---	---	---	---	.99
Ag.......	---	.48	---	---	.60	---	---	.29	.47	---	---	.63	---	---	---	.45
As.......	NA	NA	NA	NA	NA	NA	NA	.02	---	---	---	.56	---	---	---	.22
Au.......	NA	NA	NA	NA	NA	NA	NA	.00	---	---	---	.76	---	---	---	.05
B........	---	---	---	.77	---	---	---	1.0	---	---	.43	---	---	---	---	.96
Ba.......	---	.68	---	.43	---	---	---	.99	---	---	---	---	---	.70	---	.60
Be.......	---	---	.59	---	---	---	---	.91	---	---	---	---	---	---	.67	.13
Bi.......	NA	NA	NA	NA	NA	NA	NA	.00	---	---	---	---	---	---	---	.12
Cd.......	NA	NA	NA	NA	NA	NA	NA	.00	---	---	---	---	.82	---	---	.02
Co.......	.88	---	---	---	---	---	---	.99	.85	---	---	---	---	---	---	.88
Cr.......	.65	---	---	---	---	---	---	1.0	---	---	.76	---	---	---	---	.97
Cu.......	.78	---	---	---	---	---	---	.99	.82	---	---	---	---	---	---	.95
La.......	---	---	.70	---	---	---	---	.92	---	.73	---	---	---	---	---	.89
Mo.......	---	.80	---	---	---	---	---	.25	---	---	---	---	.47	---	---	.10
Nb.......	---	---	.54	---	---	---	---	.13	---	.65	---	---	---	---	---	.52
Ni.......	.80	---	---	---	---	---	---	.99	.86	---	---	---	---	---	---	.93
Pb.......	---	---	.42	---	.48	---	---	.97	.64	---	---	---	---	---	---	.91
Sb.......	NA	NA	NA	NA	NA	NA	NA	.00	---	---	---	.65	---	---	---	.03
Sc.......	.62	---	---	---	---	---	---	.99	---	.65	---	---	---	---	---	.81
Sn.......	---	---	---	---	.67	---	---	.05	---	---	---	---	---	---	---	.37
Sr.......	---	---	---	---	---	.81	---	.86	---	---	---	---	---	.70	---	.86
V........	.66	---	---	---	---	---	---	1.0	---	---	.81	---	---	---	---	.99
W........	NA	NA	NA	NA	NA	NA	NA	.00	---	---	---	---	---	---	.63	.24
Y........	---	---	.74	---	---	---	---	1.0	---	.80	---	---	---	---	---	.98
Zn.......	---	.54	---	---	---	---	---	.20	---	---	---	---	.75	---	---	.20
Zr.......	---	---	.75	---	---	---	---	.99	---	.71	---	---	---	---	---	.20
Th.......	NA	NA	NA	NA	NA	NA	NA	.00	---	---	---	---	---	---	---	.10
Au-aa....	---	---	---	---	---	---	.78	.10	NA	NA	NA	NA	NA	NA	NA	---
Zn-aa....	---	.60	---	---	---	---	---	1.0	NA	NA	NA	NA	NA	NA	NA	---
Percent of total variance explained by factor.....	23	13	10	7	5	5	4		21	12	9	7	5	5	3	

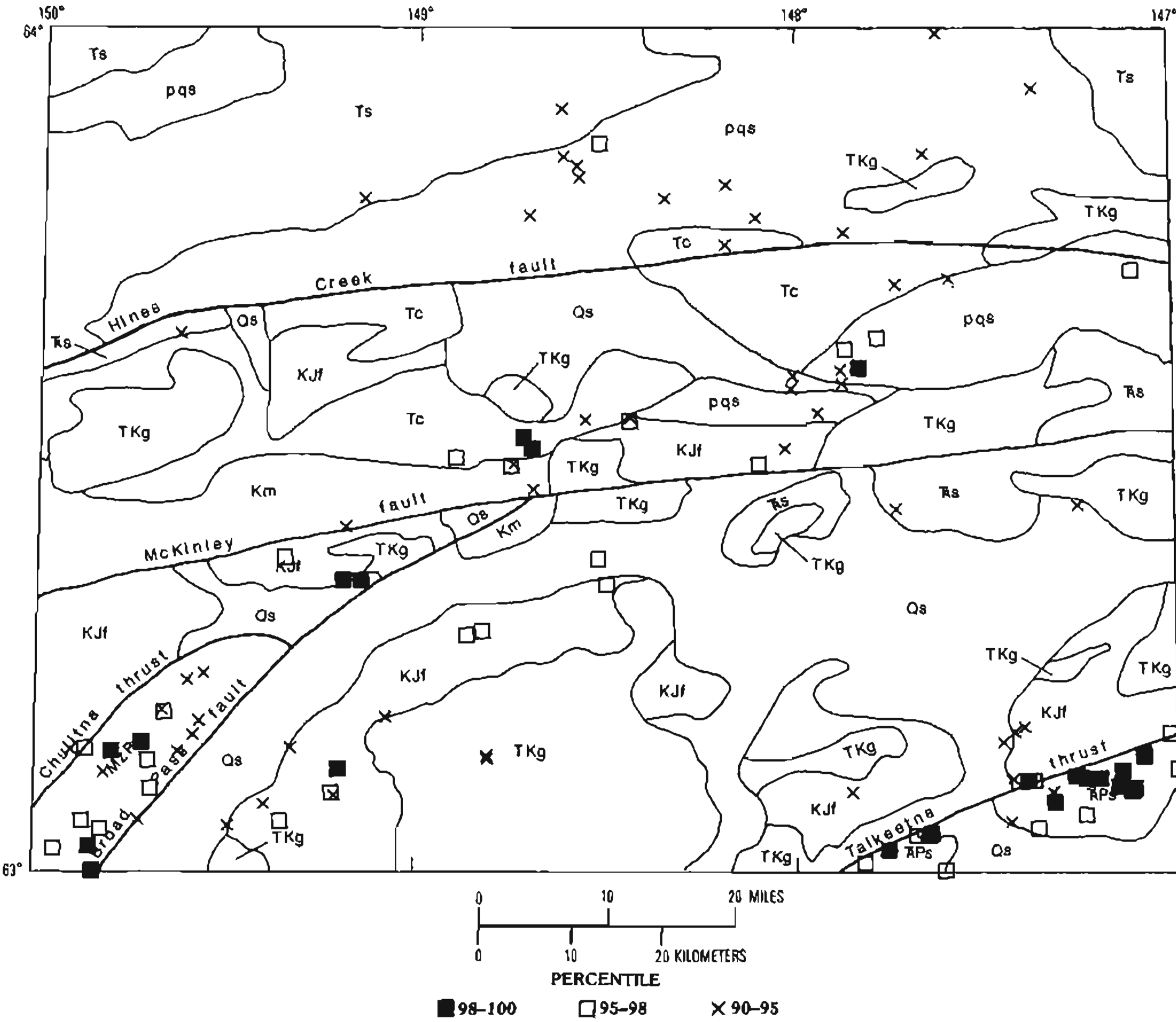

Figure 3. Distribution plot for upper 10 percentile of varimax factor 1S (Co, Ni, Cu, Fe, V, Cr, Sc, and Mg). For geology explanation, see figure 2.

Factor 1S (fig. 3) is a lithologic association of Co, Ni, Cu, Fe, V, Cr, Sc, and Mg that reflects mafic and ultramafic rocks in the Wrangellia and Chulitna terranes as well as scattered occurrences of mafic volcanic and intrusive rocks in the Devonian Yanert Fork sequence, the Jurassic and Cretaceous flysch, and the Tertiary Cantwell Formation. (See plate 1 for geographic names and more detailed geology.)

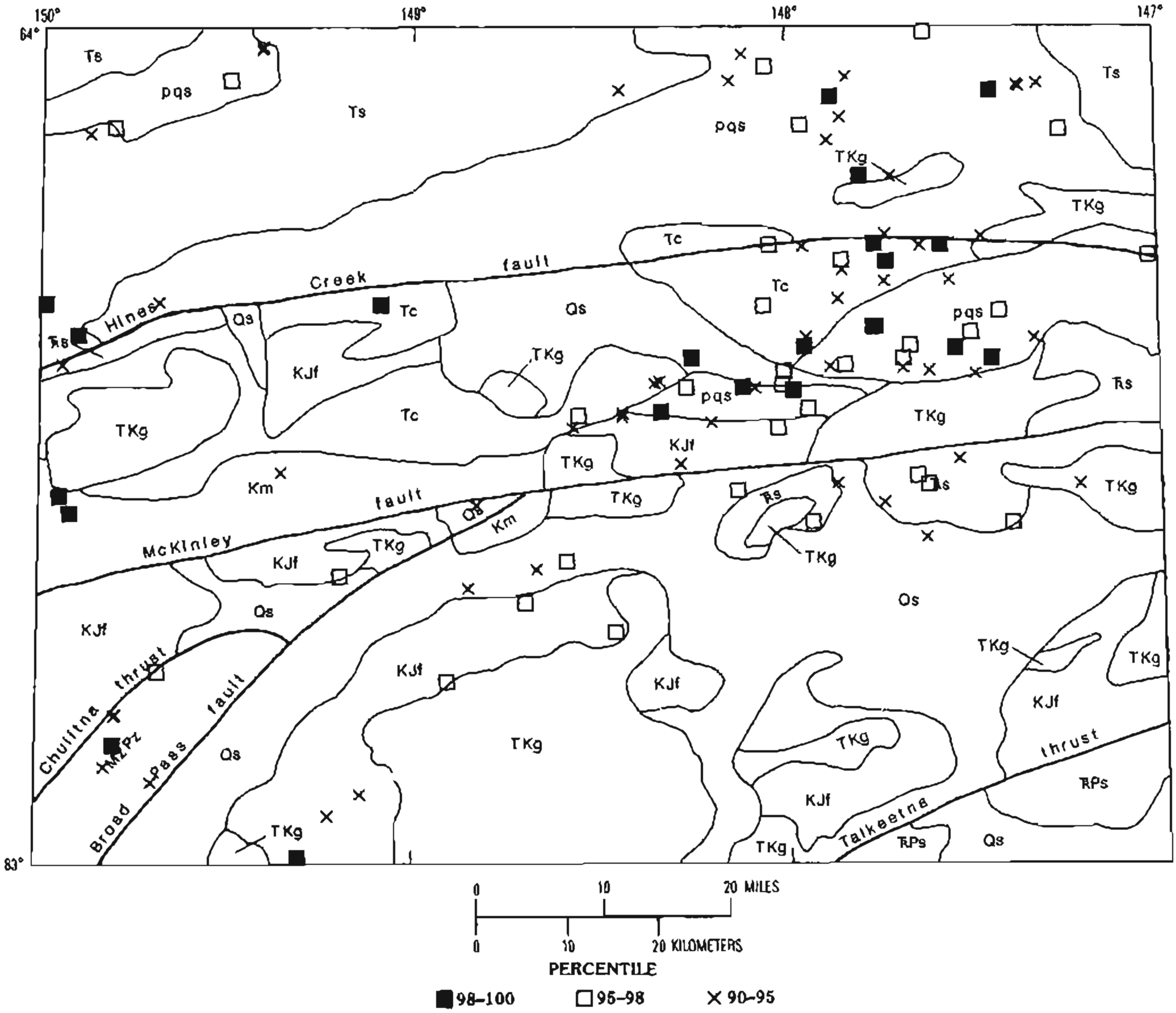

Figure 4. Distribution plot for upper 10 percentile of varimax factor 2S (Mo, Ba, Zn, and Ag). For geology explanation, see figure 2.

Factor 2S (fig. 4) has high loadings for Mo, Ba, Zn, and Ag. Samples with high factor-2S scores plot mostly in the northeastern part of the quadrangle, but there are several scattered high scores along the western border of the quadrangle and near Honolulu. High factor-2S scores are possibly related to volcanogenic massive sulfide mineralization in the Yukon-Tanana terrane and polymetallic veins in the Honolulu area.

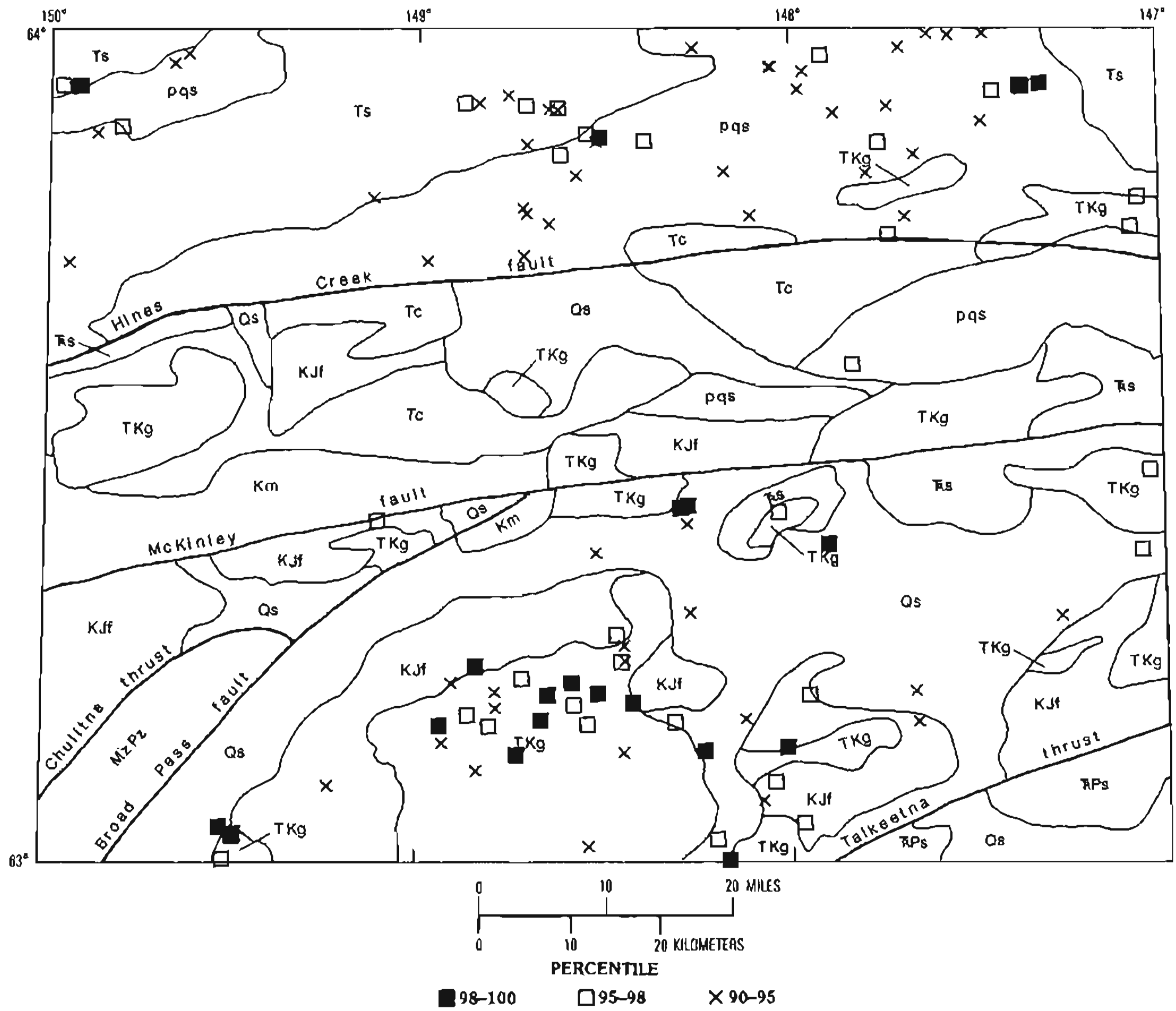

Figure 5. Distribution plot for upper 10 percentile of varimax factor 3S (Zr, Y, La, Be, Nb, and Pb). For geology explanation, see figure 2.

Factor 3S (fig. 5), with high loadings for Zr, Y, La, Be, Nb, and Pb, is dominantly a rare-earth lithophile enrichment associated with Tertiary felsic, volcanic, and granitic rocks. Samples with the highest varimax scores for this factor plot in the south-central and northeastern parts of the quadrangle.

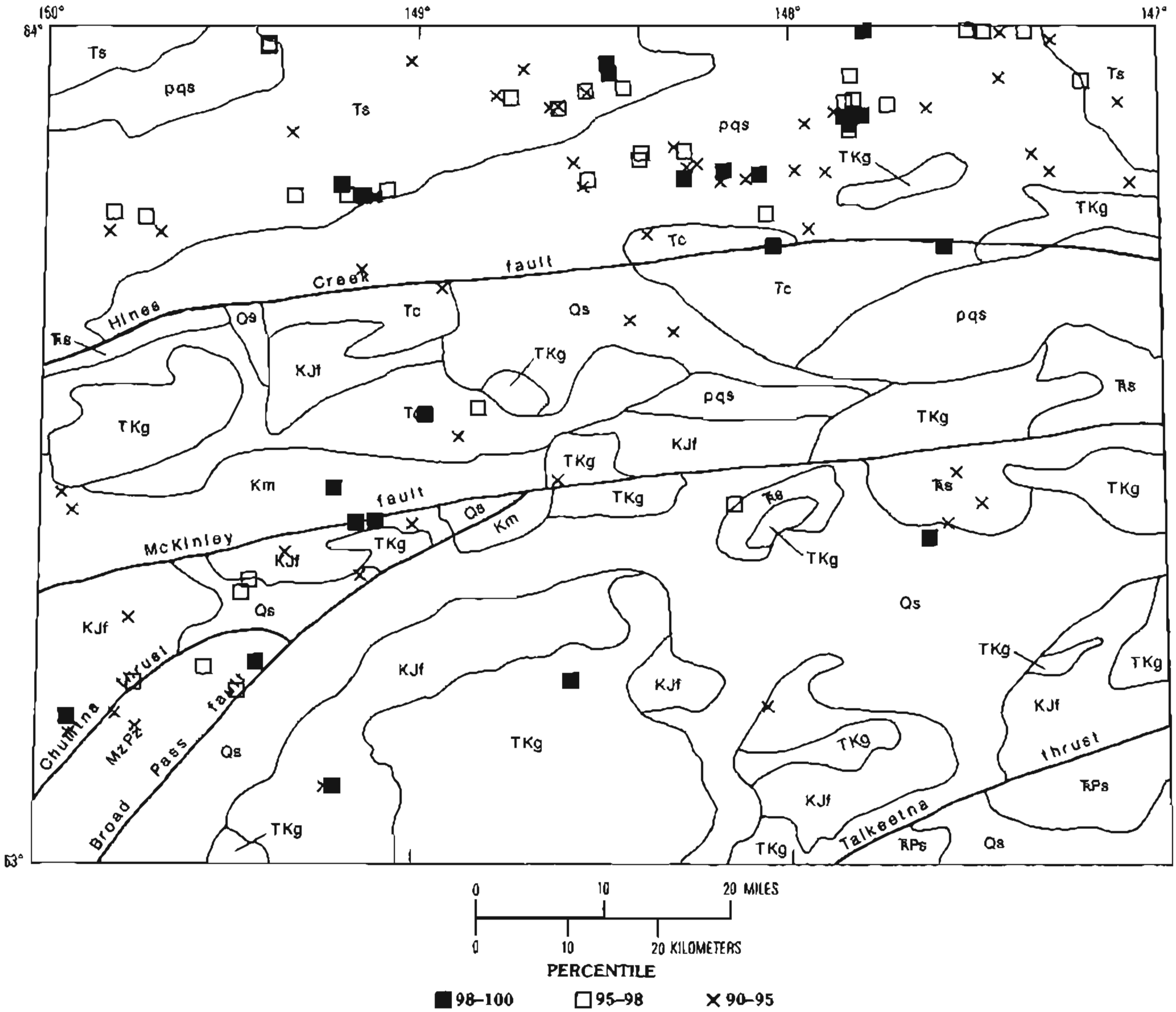

Figure 6. Distribution plot for upper 10 percentile of varimax factor 4S (B and Ba). For geology explanation, see figure 2.

Factor 4S (fig. 6) has strong loadings for B and Ba and indicates a lithologic association in the pelitic schists and the Tertiary coal-bearing rocks (Tcb) in the Yukon-Tanana terrane. High factor-4S scores in the southwestern part of the quadrangle are associated with areas of hydrothermal mineralization in the Chulitna district.

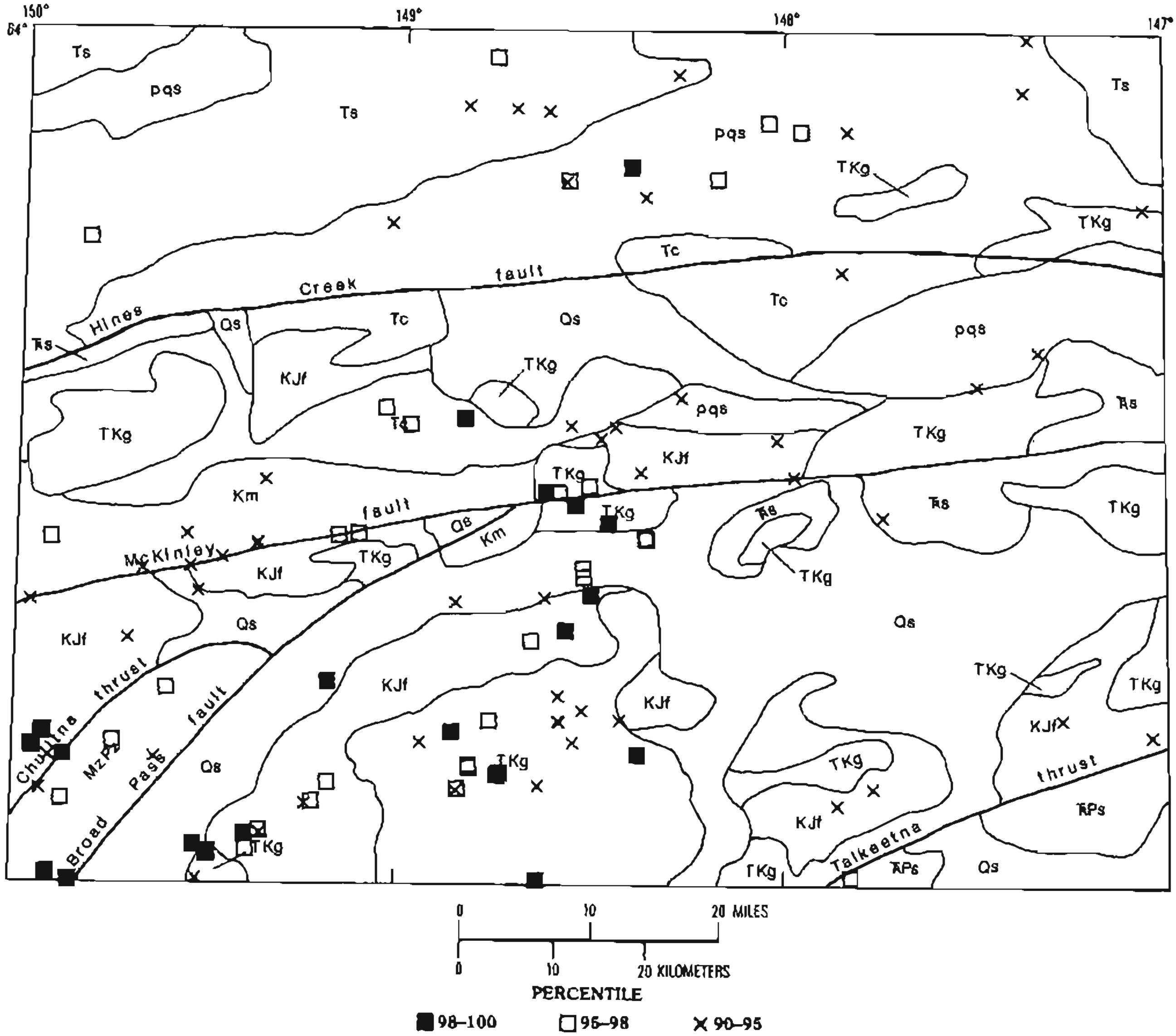

Figure 7. Distribution plot for upper 10 percentile of varimax factor 5S (Sn, Ag, and Pb). For geology explanation, see figure 2.

Factor 5S (fig. 7) contains high varimax loadings for Sn, Ag, and Pb. This factor represents mineralization associated with Sn-greisen in the Ohio Creek area and potentially similar deposits associated with Tertiary granitic rocks in the Honolulu area, to the south of Caribou Pass, in Edmonds Creek, and to the west of Pyramid Peak. Several high scores for this factor in pelitic schist between Dora Peak and Wood River probably reflect remobilization and concentration of metals by hydrothermal fluids near granitic intrusions.

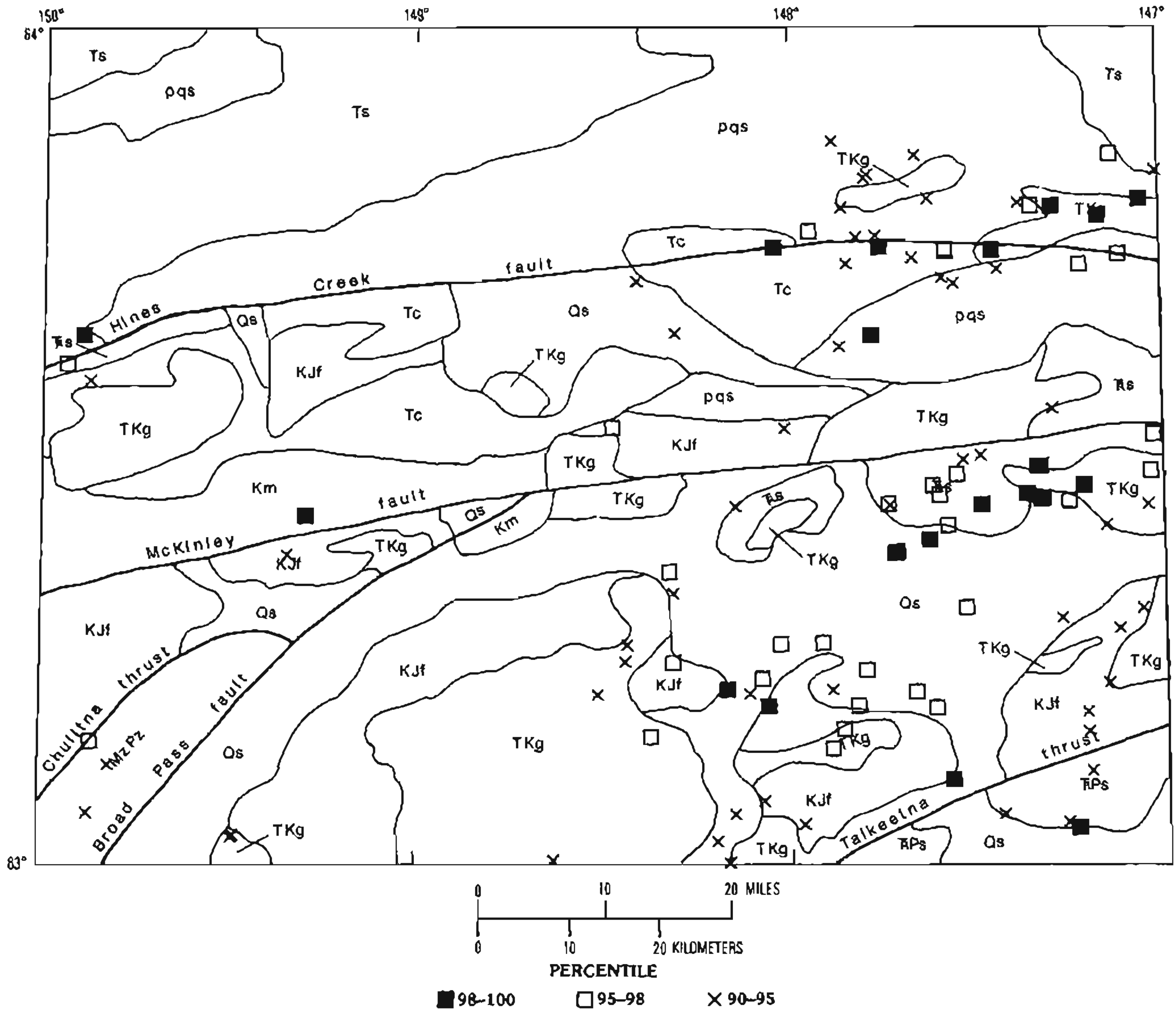

Figure 8. Distribution plot for upper 10 percentile of varimax factor 6S (Cr, Sr, Mg, and Mn). For geology explanation, see figure 2.

Samples with high varimax scores for factor 6S (fig. 8) have high correlations for Ca, Sr, Mg, and Mn. This association illustrates the distribution of pyroxenes and amphiboles in altered diabase and gabbro within the Triassic calcareous sedimentary rocks. Both the igneous rocks and the sediments have been regionally metamorphosed to greenschist and amphibolite facies assemblages (Csejtey and others, 1986), which also strengthens the association for this factor. The distribution of samples with high factor-6S scores in the Jurassic and Cretaceous flysch in the southeastern part of the quadrangle also reflects a higher degree of metamorphism of the flysch in this area than in other parts of the quadrangle, and illustrates the trend of the Maclaren metamorphic belt of Smith (1974).

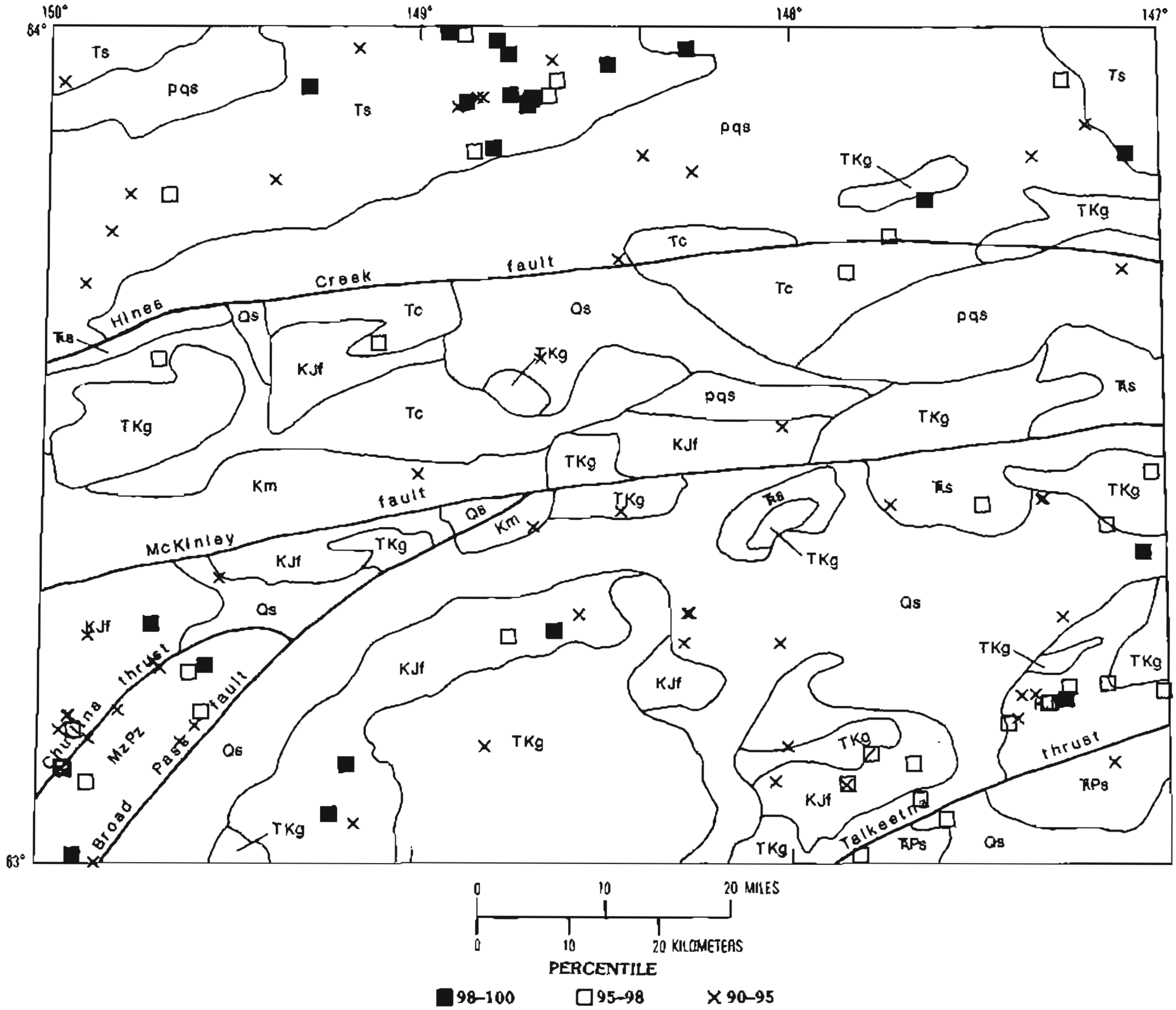

Figure 9. Distribution plot for upper 10 percentile of varimax factor 7S (Au). For geology explanation, see figure 2.

Factor 7S (fig. 9) is dominated by high loadings for Au. Samples with high scores for this factor define placer gold in four areas: (1) the Tertiary coal-bearing rocks and Nenana Gravel around Jumbo Dome, (2) gold in lode and placer deposits in the Valdez Creek area and Gold Creek area further southwest, (3) gold associated with hydrothermal mineralization in the Chulitna district, and (4) scattered gold occurrences in the Triassic calcareous sedimentary rocks, usually near intrusions of Cretaceous granite.

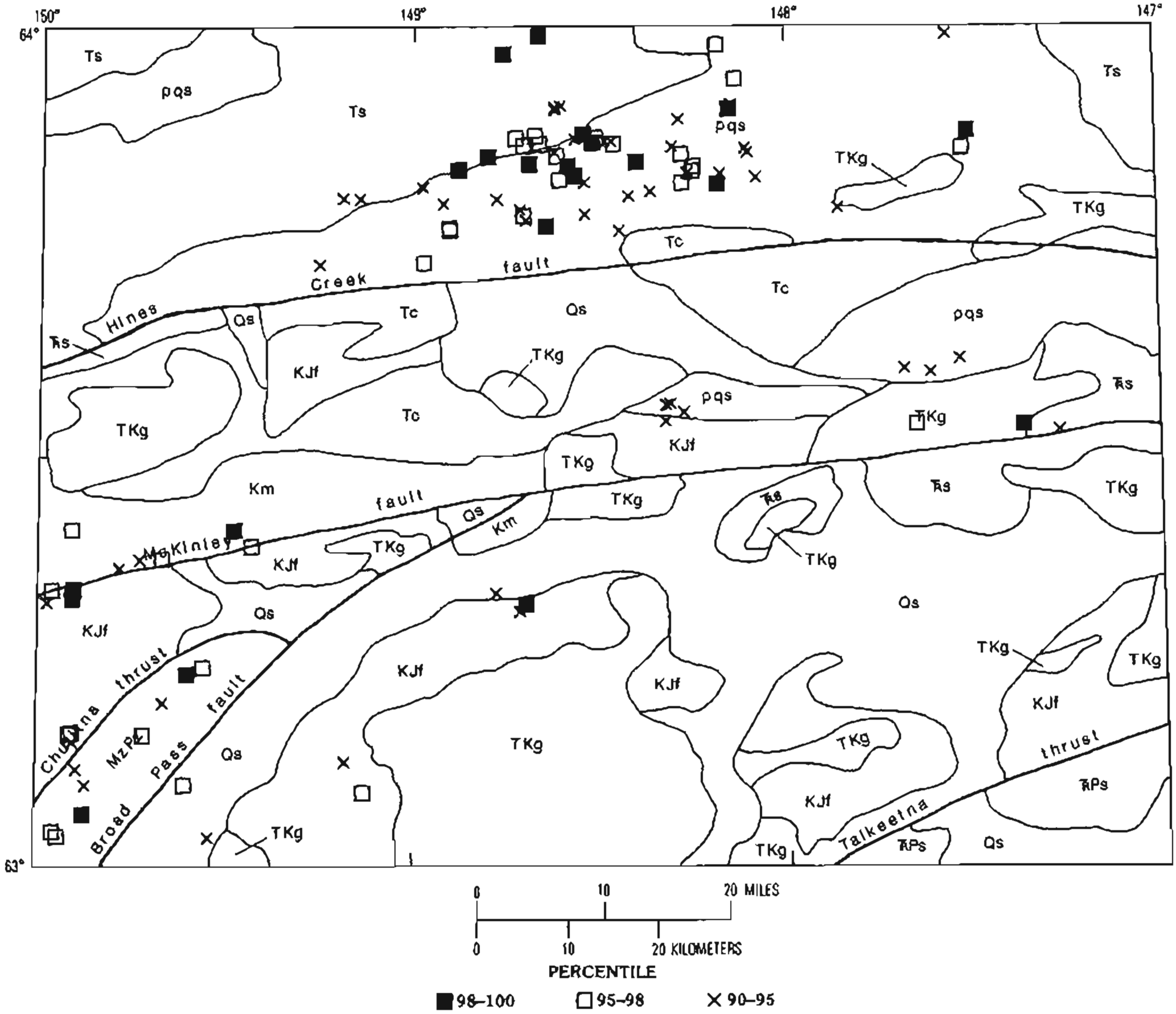

Figure 10. Distribution plot for upper 10 percentile of varimax factor 1C (Fe, Ni, Co, Cu, Pb, and Ag). For geology explanation, see figure 2.

Factor 1C shows strong loadings for Fe, Ni, Co, Cu, Pb, and Ag related to areas of sulfide mineralization in the pelitic quartz-sericite schist between the community of Healy and the Wood River, in the Chulitna district, and along the McKinley fault west of Cantwell Creek (fig. 10). Other areas with high factor-1C scores are near Dry Creek, between West Fork and Yanert Glaciers, to the north of Pyramid Peak and along the Jack River.

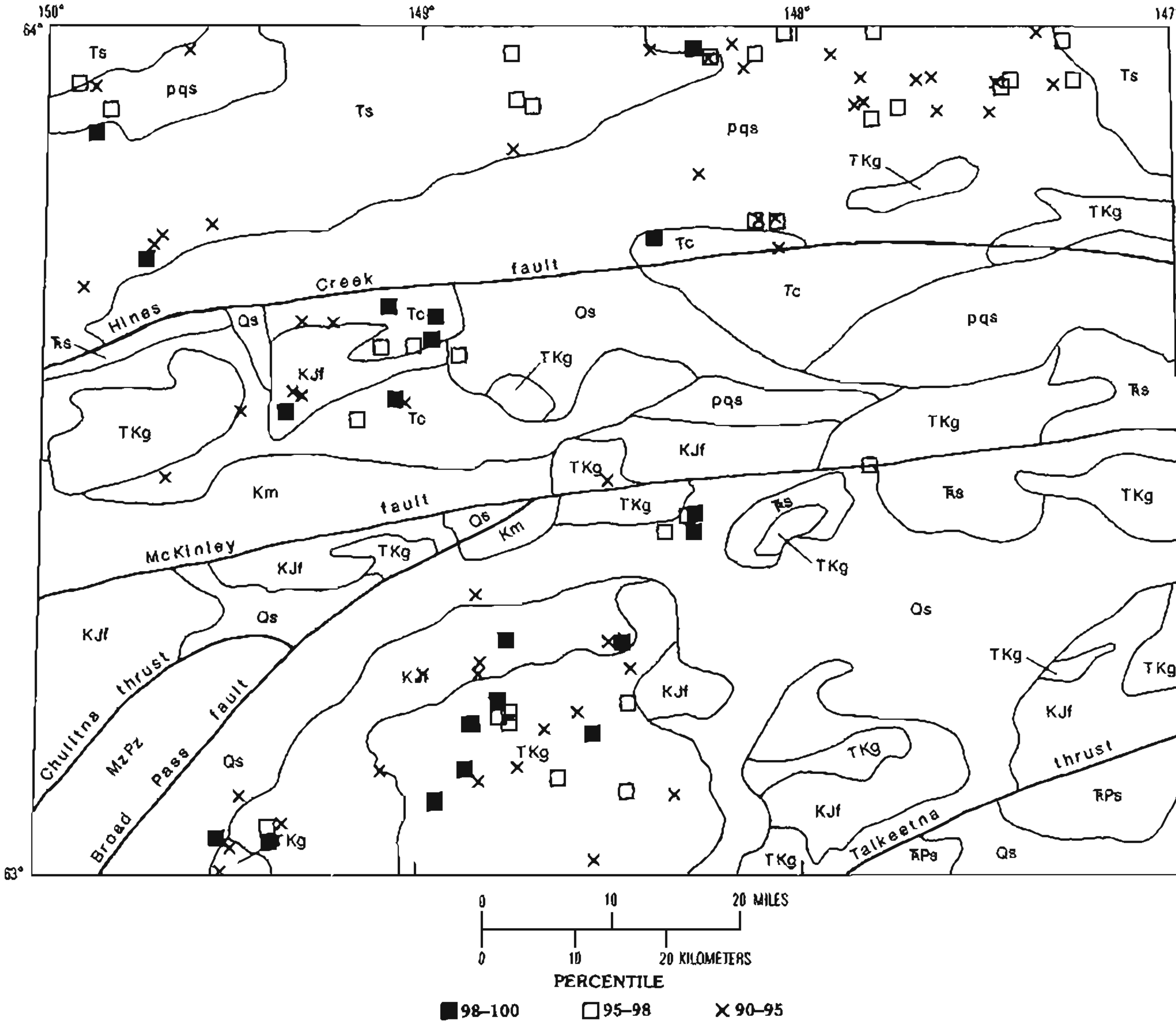

Figure 11. Distribution plot for upper 10 percentile of varimax factor 2C (Y, Ti, La, Zr, Nb, and Se). For geology explanation, see figure 2.

Factor 2C (fig. 11) is dominated by a rare-earth association similar to that of factor 3S and reflects the distribution of Tertiary volcanic and granitic rocks in the south-central part of the Healy quadrangle, in the area north of Fang Mountain, and along the northern boundary of the quadrangle.

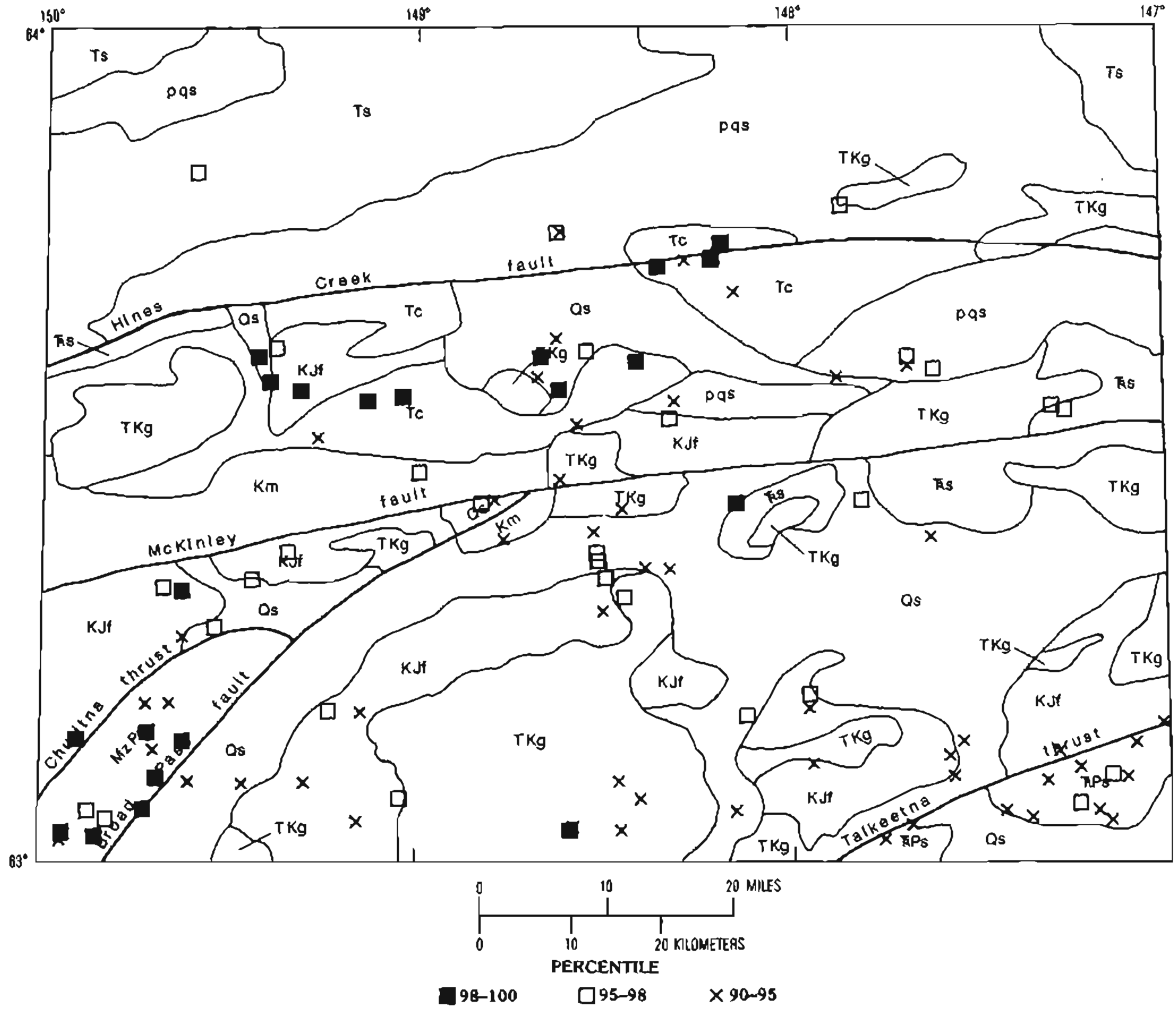

Figure 12. Distribution plot for upper 10 percentile of varimax factor 3C (Mg, Mn, V, Cr, Co, and B). For geology explanation, see figure 2.

Factor 3C is a lithologic assemblage with high varimax loadings for Mg, Mn, V, Cr, Co, and B (fig. 12). Samples with high factor-3C scores are concentrated in mafic and ultramafic rocks in the Chulitna and Wrangellia terranes. The predominance of high factor-3C scores in samples from the Tertiary Cantwell Formation is unexplained, but may represent local Tertiary mafic intrusions.

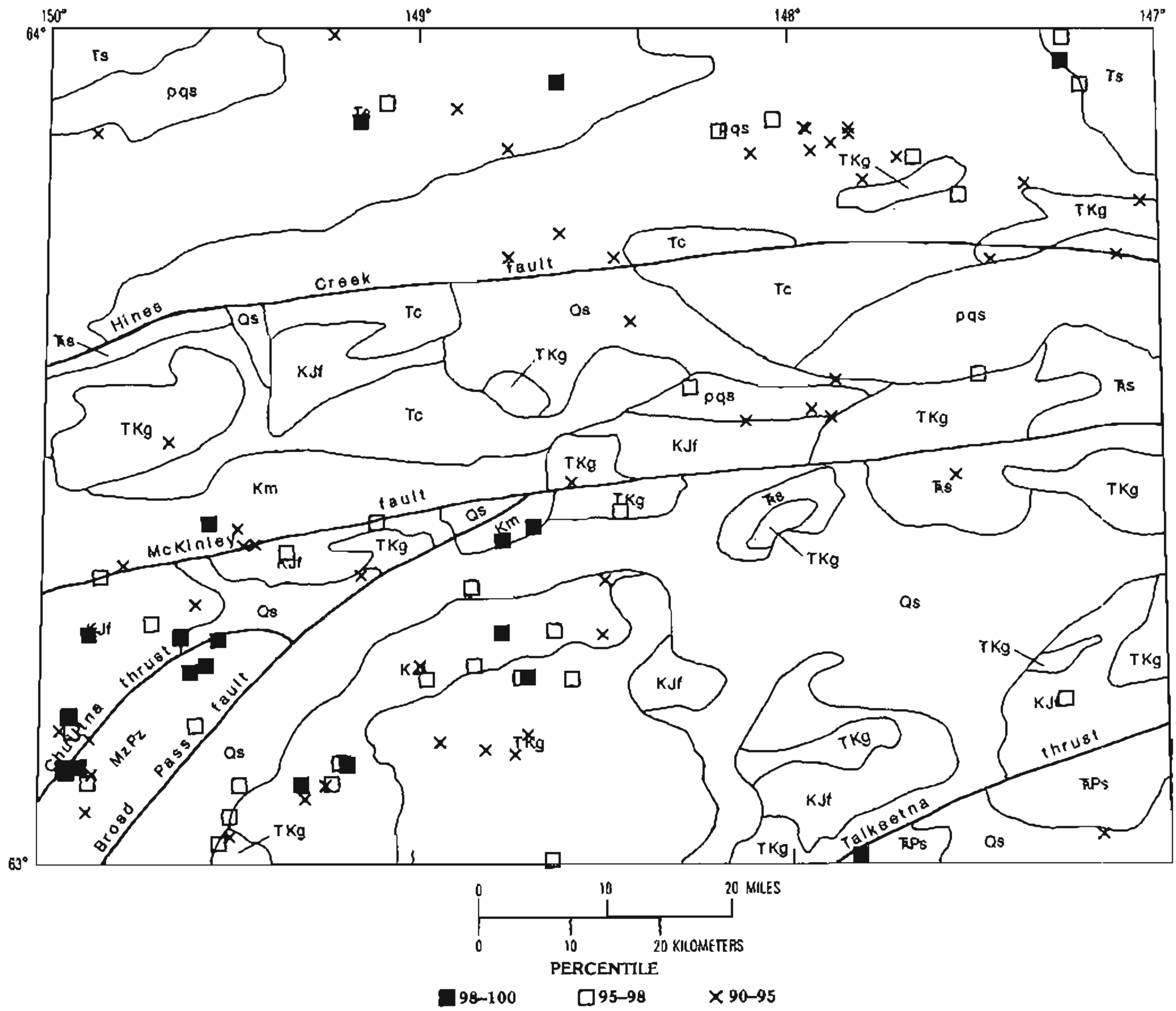

Figure 13. Distribution plot for upper 10 percentile of varimax factor 4C (Au, Sb, Ag, and As). For geology explanation, see figure 2.

Factor 4C (fig. 13) has high varimax loadings for Au, Sb, Ag, and As and reflects mineralization in the Lookout Mountain and Ohio Creek areas of the Chulitna district. Samples near Tertiary granitic rocks north of Honolulu and felsic volcanic rocks south of Caribou Pass also had high factor-4C scores and may reflect mineralization from a buried pluton. High factor-4C scores for samples derived from the pelitic quartz-sericite schist in the vicinity of Copper Creek and Kansas Creek is an expression of hydrothermal mineralization related to Cretaceous granitic intrusions in this area.

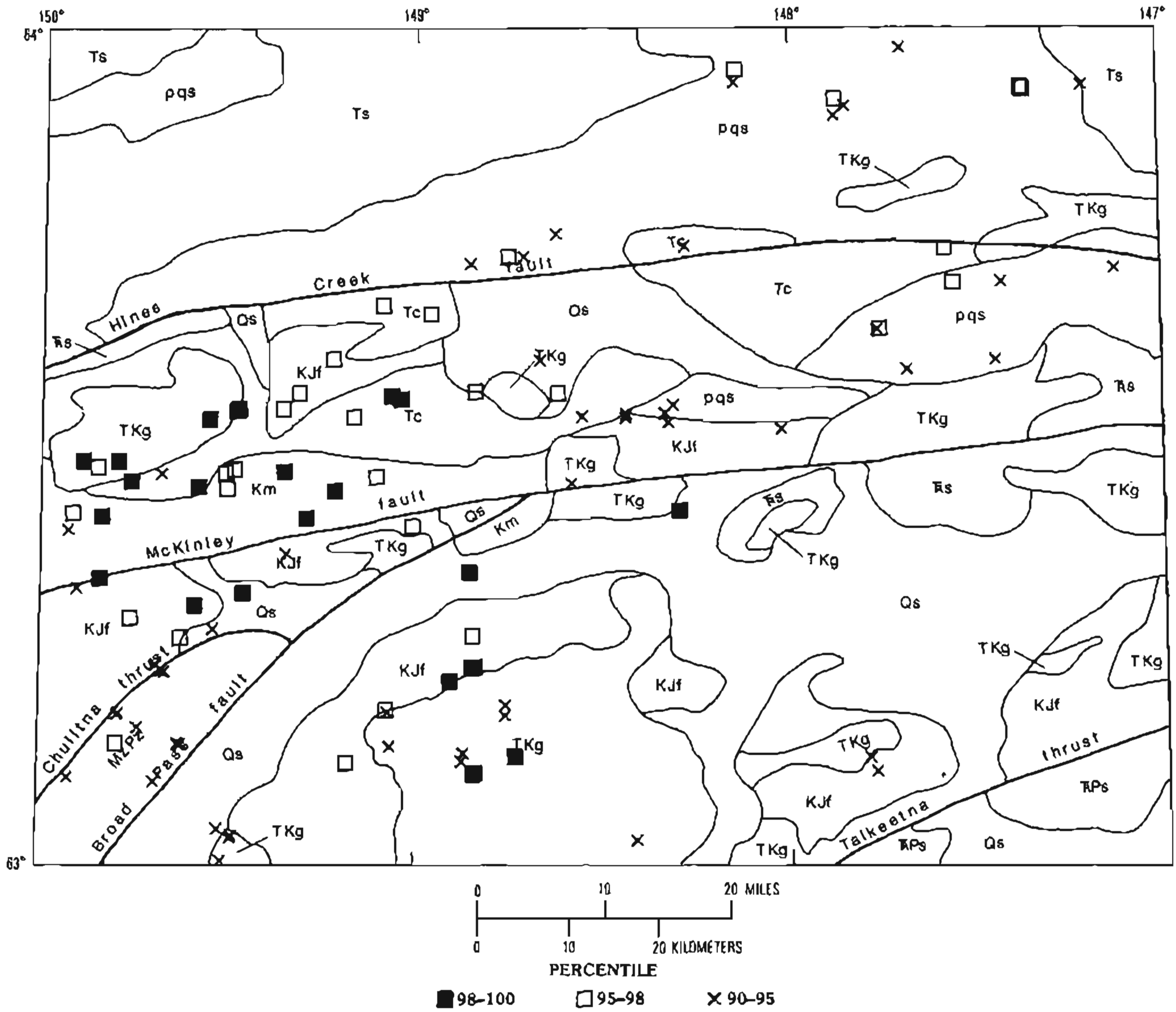

Figure 14. Distribution plot for upper 10 percentile of varimax factor 5C (Cd, Zn, and Mo). For geology explanation, see figure 2.

Factor 5C, Cd, Zn, and Mo, is an assemblage that mostly occurs in samples derived from areas underlain by the Tertiary Cantwell Formation, Tertiary felsic rocks, and a Paleozoic sedimentary rock sequence north of the McKinley fault (fig. 14). High factor-5C scores are associated with Tertiary volcanic rocks north of the McKinley fault and west of Sanctuary River, to the south of Caribou Pass, between the headwaters of Revine and Moose Creeks and suggest the possibility of mineralization related to buried plutons in these areas. The Paleozoic sequence west of the Nenana River and north of the McKinley fault contains abundant limestones and may be a host for local skarn or replacement mineralization. High factor-5C scores for samples from the Tertiary Cantwell Formation east of Fang Mountain are unexplained, but may be due to local Tertiary intrusions.

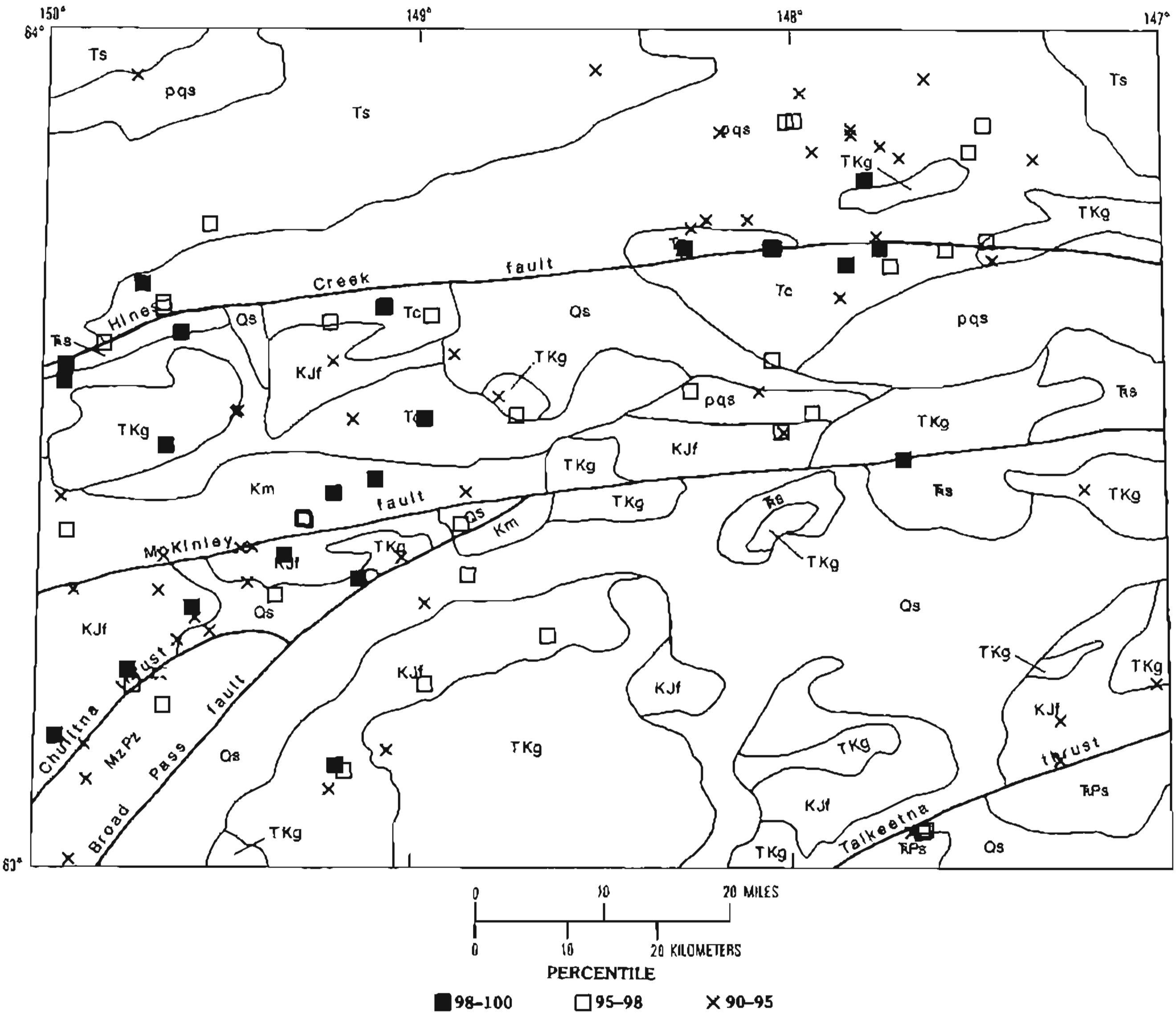

Figure 15. Distribution plot for upper 10 percentile of varimax factor 6C (Sr and Ba). For geology explanation, see figure 2.

Factor 6C is an Sr and Ba association that illustrates the distribution of abundant barite in the southwestern, west-central, and northeastern parts of the quadrangle (fig. 15). Because barite was nearly ubiquitous throughout the Healy quadrangle (401 of 1,045 samples contained more than 5,000 ppm barium, the upper level of determination), the distribution of samples with high scores for factor 6C is highly scattered. The Tertiary Cantwell Formation, Jurassic and Cretaceous flysch, Triassic calcareous sedimentary rocks, and Precambrian or Paleozoic pelitic schists are the rock units from which most of the samples with high scores for factor 6G were derived.

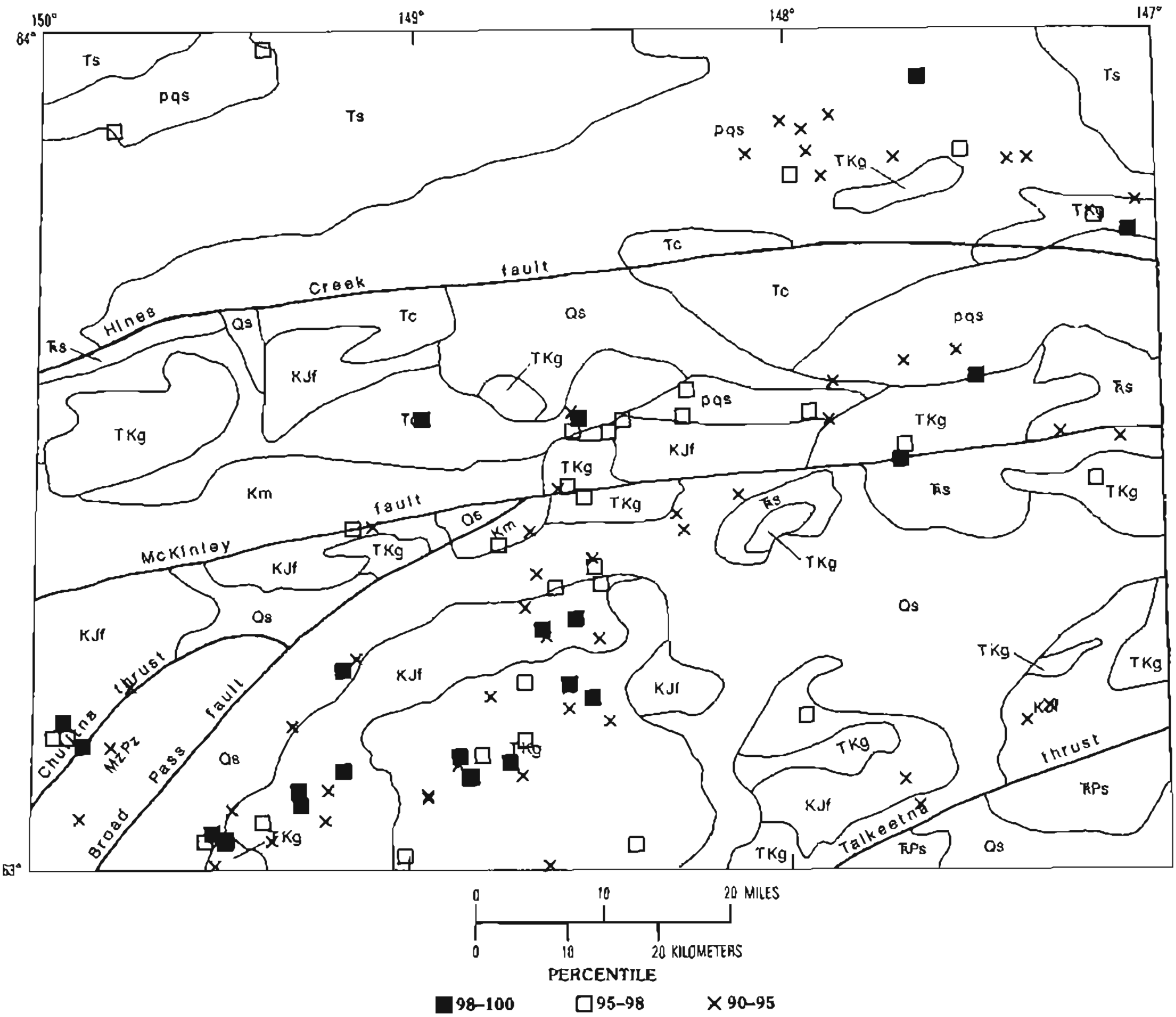

Figure 16. Distribution plot for upper 10 percentile of varimax factor 7C (Be and W). For geology explanation, see figure 2.

Factor 7C (fig. 16) is controlled by Be and W, which are associated with mineralization in the Chulitna district and near Honolulu, in the vicinity of Caribou Pass, east of Panorama Mountain, between West Fork and Yanert Glaciers, and along the Copper Creek-Kansas Creek trend. The elements in this factor have a high percentage of qualified values that were replaced, and there is probably some induced correlation inherent in this process. However, the localities with the highest factor scores are consistent with anomalously high values in the data set and closely follow the trend of tin mineralization described by Light and others (1989). If Au, Cd, and Sb are deleted from the data set, because of low detection ratios, then Bi, Sn, and W load strongly into factor 4C with Ag and As.

SUMMARY AND CONCLUSIONS

The known mineral deposits, the distribution of ore-related minerals in heavy-mineral-concentrate samples (Tripp and others, 1989), and the anomalously high concentration of selected elements in stream-sediment (King and others, 1989) and heavy-mineral-concentrate samples (Light and others, 1989) indicate that the Healy quadrangle contains a diverse and widespread group of mineral occurrences. Cu and placer-Au occurrences in the southeast corner of the quadrangle have been previously described, as have been the breccia pipes containing Cu, Au, Ag, Pb, and Zn at the Golden Zone mine and at similar occurrences in the Upper Chulitna district in the southwest corner of the quadrangle.

Most of the geochemically anomalous areas in the Healy quadrangle fall within two distinct mineralized provinces: (1) the Precambrian or Paleozoic schists containing volcanogenic massive sulfide and Cretaceous(?) vein-type deposits in the northeastern part of the quadrangle; and, (2) mineralization associated with tin-bearing granitic plutons and other Tertiary felsic intrusive and volcanic rocks in the southwestern quarter of the quadrangle. Arsenopyrite, barite, chalcopyrite, galena, gold, scheelite, and sphalerite occur throughout both these areas. The following major mineral-deposit types are known to be present or are indicated by the geochemical associations and distributions of trace elements and by the mineralogy of heavy-mineral concentrate samples:

1. Volcanogenic massive sulfides.
2. Tin-bearing greisens and associated tin veins.
3. Porphyry-related copper and porphyry molybdenum with associated breccia, vein, and skarn deposits.
4. Polymetallic veins.
5. Skarn and disseminated replacement deposits.
6. Low-sulfide gold.
7. Podiform chromite.
8. Placer gold.

Geochemical anomalies characteristic of volcanogenic massive sulfide deposits occur throughout the Precambrian or Paleozoic schists, argillites, and phyllites north of the Hines Creek fault from Dora Peak to the eastern boundary of the quadrangle. Volcanogenic massive sulfide deposits may also occur in the area of Jurassic and Cretaceous flysch south of the McKinley fault and west of Monahan Flat.

Reed and Lanphere (1973) and Lanphere and Reed (1985) described the McKinley sequence of highly evolved, siliceous granites southwest of the Healy quadrangle. Granites of this sequence are known to be associated with Sn-bearing greisen occurrences in Coal Creek, a few miles south of the quadrangle, and in Ohio Creek, in the southwest corner of the quadrangle. Cassiterite and high tin concentrations in drainage basin samples are associated with Tertiary granitic intrusion in the area south of the Yanert Fork and west of Monahan Flat. Where cupolas have formed in granitic plutons in the southwestern, south-central, and central parts of the quadrangle, similar Sn-bearing greisens are expected to occur.

Porphyry-related copper, similar to the Golden Zone deposit in the northern part of the Chulitna terrane, and possibly copper-molybdenum deposits with associated breccia, vein, and skarn deposits are expected to occur in the Honolulu area, upper Jack River area, Upper Revine Creek, near Nenana Mountain, upper Yanert Glacier, and lower West Fork Glacier.

Polymetallic vein deposits are possible throughout the Healy quadrangle, especially near Cretaceous and Tertiary intrusions. The geologically and geochemically most favorable areas are the Chulitna terrane, upper Jack River area, Copper Creek-Kansas Creek-Glory Creek trend, and the Valdez Creek district.

Skarn and disseminated replacement deposits can be expected to occur in limestone-rich areas of the Triassic calcareous sedimentary rocks and the Jurassic and Cretaceous flysch near intrusive contacts with Cretaceous or Tertiary granitic intrusions.

Gold-bearing quartz veins produced by metamorphic remobilization of siliceous fluids in the Jurassic and Cretaceous flysch may occur in areas of greenschist-facies metamorphism to the south of the McKinley fault and west of Monahan Flat.

Small podiform chromite occurrences have been described in the serpentines of the Chulitna terrane (Hawley and Clark, 1974) and similar deposits that may occur are probably restricted to this area.

Placer gold could occur from erosion of most of the deposit types just described. However, the most favorable areas are in the vicinity of Valdez Creek and in the Chulitna district. The occurrence of gold in sediments from the Tertiary Nenana Gravel and coal-bearing rocks and not in heavy-mineral concentrates indicates that the gold is probably fine grained and may be difficult to detect in these areas.

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______ 1970d, Geologic map of the Healy D–5 quadrangle: U.S. Geological Survey Geologic Quadrangle Map GQ–807, scale 1:63,360.

Appendix—Distribution of anomalously high concentrations of selected elements in stream-sediment and heavy-mineral-concentrate samples

[Loc. No., sample locality number shown on plate 1. Elements in parentheses fall within the 95–98 percentile range; all others are in the 98–100 percentile range. Leaders (---) indicate no anomalously high concentrations of the selected elements]

Element Anomalies					
Loc. No.	Sediments	Concentrates	Loc. No.	Sediments	Concentrates
1	(Mn, Zn)	Sn	72	---	(Be)
2	---	Be	73	Ag (Be, Sn)	(Ag, Be)
4	Pb	(Ni)	76	Be	Ag, Sn (Be)
6	---	Fe, Ni (Bi, Pb)	77	---	(Be)
7	---	(Au)	79	---	Bi
8	(Au)	---	80	---	Cd
9	---	Fe (Co, Ni)	83	---	(Ag, Au)
10	---	Fe (Co)	84	(Mo)	Cd, Mo (Zn)
11	---	(Au)	85	(Be)	---
12	(Mn)	---	86	---	Sb (Au, Zn)
15	(Mn)	---	87	---	Cu (Sb, W)
19	---	Ag, Zn (Pb)	88	(Ag, Pb, Sn, Zn)	Cu, Mo
20	Au (Sn)	Ag, Au, Cu, Sn, W (B, Bi)	90	(Ag)	---
21	(Mn)	(Cu)	95	---	(B)
22	---	---	97	---	B
23	---	B	98	As, Sn (Ag)	As, Sn (Ag, B, Bi)
24	Mn (Au)	---	100	Mn	---
25	(Au, Mo, Sn, Zn)	Zn	101	(Mn)	---
26	(Sn)	Sn	102	---	Mo, Th (Bi)
27	---	As, Bi, Cu, Sn (W)	103	---	Bi, Th
28	---	As, Bi, W (B)	105	---	Th
29	---	Au, Cu (Ag, B, W)	106	---	(Bi, Th)
30	Mo (Zn)	---	112	---	(Cr)
31	---	Sn	113	---	(Pb)
32	Sn	Cu, Sn, Th (B)	114	Mn (Mo, Zn)	Cu (Be, Co, Pb)
33	Sn	Cu, Sn (W, Th)	115	---	(Cu)
34	---	Bi, Sn	116	---	Au (Ag)
35	Ag (Be, Pb, Sn)	Ag, Be, Cu, Sn (Au, Mo)	117	(Au)	(Bi, Cu, Mo, Pb)
36	---	Be	118	(Ag, Be)	Sn (Be)
37	(Sn)	Th (Ag, Mo)	120	Au	Sn (Ag, Au)
38	---	Sn (Th)	122	Sn (Au, Be)	Be, Sn (Bi)
39	---	Au, Sn (Ag, Cr)	124	---	As (Sb, W)
40	---	W	125	(Mo)	---
41	---	---	131	(Sn)	---
43	---	Be	134	---	Bi, Sn (Be, Th)
45	(Mn)	---	135	(Sn)	Sn, Th
46	---	---	136	Sn (Be)	Sn
48	---	Fe (Mo)	137	Ag, Sn	Sn (Ag, Au, Th)
52	(Sn)	---	138	---	Sn
53	(Zn)	---	139	---	Fe
55	(Be)	Bi, Cd, Cu, Mo, Th, Zn, (Ag, Be)	140	(Ag)	---
56	Sn (Zn)	Mo (Cu)	141	---	Fe (Co)
57	(Sn)	Bi, Sn (Be, Th)	142	---	Fe, Co
58	---	(Mo, W)	143	---	(Th)
59	---	(Au)	144	---	(Cr)
61	---	Sn (Be)	146	---	Fe
62	Sn	Be, Sn (As, B)	146	---	(B, Th, W)
63	---	Zn (Mo)	147	---	Co (Th)
64	---	(Zn)	148	---	B
65	---	(Zn)	149	(B)	(B)
66	---	Sn	151	(Au)	---
67	---	Bi, Th (Be)	156	---	(Bi)
68	---	Be, Th	157	---	B
70	---	Fe	158	---	(B, Cu)
71	(Be)	(Be)	159	(Au, Mn)	---

Appendix—Distribution of anomalously high concentrations of selected elements in stream-sediment and heavy-mineral-concentrate samples—Continued

	Element Anomalies				
Loc. No.	Sediments	Concentrates	Loc. No.	Sediments	Concentrates
161	(Mn)	(B)	261	Mo	---
162	Mn	B	268	Mo	---
164	(Au)	---	271	---	(Ag, Au)
165	(Ag, Mo)	(B)	274	Mn	---
166	(Au)	---	278	---	(Cr)
174	(Mn)	---	281	As (Mo, Sn)	B, Sb, Sn
177	(Ag)	Zn	282	As (Mo, Zn)	---
178	(Ag)	---	283	---	Sn
180	(Cu)	---	286	---	(Cr, Cu)
181	---	Sn	288	(Ag, Pb)	Ag, Cu, Pb, Sn (Bi)
190	---	(Au)	289	---	Cd (B, Zn)
193	---	(Th)	290	(Mn)	---
195	---	Sn	291	(Be)	(Be)
196	Th	Sn, Th	292	(Zn)	---
197	---	Th	293	(Au, Zn)	As, Au, Sb, W (Ag, Bi)
198	---	(Th)	294	As	Au, Sn, W (Mo)
199	Be, Sn (Zn)	Bi, Sn (Th)	295	(Ag)	---
202	(Au)	---	297	(Ag, Mn)	(B)
205	Cu	Cu	299	(Au)	---
209	(Au)	Bi (B)	300	(Au)	---
210	Au	---	301	---	(Mo)
212	(Au)	---	302	(Au)	(Mo)
214	(Mn)	---	303	Au	(Mo)
215	Mn	---	304	(Mn)	(Mo)
216	(Au)	---	305	(Au)	---
217	Cu, Mo (Ag)	---	307	(Au)	(W)
218	---	(Cu)	308	Au	(W)
219	(Ba, Mo, Zn)	---	310	(Cu)	B
220	(Au, Mo)	As, Co, Mo, W (Ag, B, Bi, Pb)	311	---	B
221	(Mo)	(As)	312	---	(B)
222	Mo	---	313	Au (Ag)	Ag, Au (Pb)
224	(Ag, Mo)	Cu	315	(Mn)	---
225	Mo (Ag, Ba, Zn)	(W)	325	Cu	---
226	---	Cu	326	(Au)	---
229	(Cu, Mo)	---	328	Cu	---
230	Mo	---	331	W (Au)	---
231	---	Th	332	Cu	---
232	Th	(Be, Th)	338	As (Cu)	---
234	(Mn, Mo, Zn)	---	339	(Cu)	---
235	Be, Cd, Cu, Mn, Zn	---	342	(Mn)	(B)
236	(Zn)	---	344	Au	Au (Ag, W)
237	Th	Th	345	(Au)	B
238	---	Bi, Cu, Sn, Th (As, Au)	346	---	(B)
240	---	Fe (Pb)	348	Mn (Au)	---
241	---	(Ni)	349	(Au, Mn)	---
242	---	(Pb)	350	---	(Au)
243	Zn	(Pb)	351	(Be)	(Be)
244	Cd (Zn)	Cd (Pb, Zn)	352	Be	---
245	Cd, Zn	(Pb)	353	(Ag)	---
246	Pb	(Zn)	354	Be	B
247	(Zn)	---	355	(Ag)	---
250	---	(Zn)	356	(Ag)	(W)
252	---	(Zn)	357	(Be)	---
253	(Au)	---	360	Ag (Sn)	Pb, Sn
254	Pb (Ag, Zn)	Fe (Ni)	364	Mn	---
255	---	Fe	367	---	(Au)
256	---	(Pb)	371	Cu	---
257	---	(Pb)	372	(Cu)	---
259	---	As, W (Pb, Zn)	373	---	(Cr)
260	(Ag, Mo)	(Ni, Zn)	374	Cu (Au)	---

Appendix—Distribution of anomalously high concentrations of selected elements in stream-sediment and heavy-mineral-concentrate samples—Continued

Element Anomalies					
Loc. No.	Sediments	Concentrates	Loc. No.	Sediments	Concentrates
376	(Au)	---	448	Ag	---
377	(Au)	---	450	(Au)	Cr, Sn
378	(Cu)	---	451	----	(Ag)
379	(Au, Mn)	---	452	---	(Ag, Au, Ni)
381	Sn (Zn)	Sn (W)	453	(Zn)	Au, Ba (Mo)
382	---	(Cr)	456	Mn	---
383	Mn (Cu)	---	457	(Cu, Sn)	---
384	(Au)	Cu, Sb (Pb, Zn)	463	---	(B)
385	As	Fe, Ag, As, Au, Cu, Sb (Pb)	467	Ba	---
386	Cu	(Cu)	468	Ba	(W)
387	Ba	(Mo, Zn)	471	---	Pb (Zn)
388	Ba, Cu	Cu	472	Zn	---
389	(Au)	As, Cu, Sn (Ag, Au, Cr)	475	(Mn)	---
390	(Au)	Cu, Sn (As, W, Zn)	481	(Mn)	(Th)
391	Ag, As, Ba,	As, Cu, Pb, Sn (Au, Be) Cu, Pb, Sn	482	---	(Th)
392	(Cu)	(Cr, Cu, W)	483	(Ag)	(Th)
393	---	(Cr)	485	---	Th (Cr)
395	---	(Cr)	487	---	Co, Th
396	Sn (Au)	(Th)	488	---	Th
397	(Cu)	As, Cu (Cr, W)	489	(Cu)	Co, Th (Bi)
398	Cu	---	490	---	(B, W)
399	---	Fe (Cu)	491	---	(B, Be, W)
400	Ba, Cu, Mn (Zn)	(Sb)	493	Ag	---
401	(B, Mn, Zn)	Cr	494	(Au)	---
402	(B)	(Cr)	496	(Ag, Mo)	---
403	---	Cu (Cr)	497	(Ag, Mo)	---
405	Ag, Ba, Cu, Pb	(As, Zn)	498	As	---
406	Ba, Cu (Au)	(Zn)	499	(Ag)	---
407	(Ba, Cu)	(Cu)	500	---	B
408	---	(Zn)	501	Mn	---
409	(Mn)	Cr	502	(Ba)	(B)
410	(Ag)	---	507	Mn	---
411	---	(Cr, W)	508	(Mn)	---
416	Ba (Mn)	---	509	(Mn)	---
417	(Mn)	(Zn)	512	(Mn)	---
418	(B)	---	513	Mn	Bi, W (B)
419	Ba	---	514	---	Bi (B)
420	---	(Zn)	515	Mn	---
421	---	Sn	516	Mn	---
422	---	Sn (Cr)	518	Mn	---
423	---	(Pb)	521	Mn	---
425	Pb	Fe, Pb	522	(Mn)	---
426	(B)	Fe, Ni (Co)	528	---	Cr
427	(Pb)	Fe (Co, Ni, Pb)	530	---	(Cr)
428	---	Fe (Co, Ni)	531	---	Cr
429	(Cu)	Fe (Ni)	534	---	Cr
430	Pb (Ag)	Ni	535	---	(Cr, Zn)
431	---	Fe (Co, Zn)	538	(Zn)	---
432	---	Fe, Ni (Co)	539	---	Cr
433	---	Fe, Ni (Co)	540	(B)	---
435	---	Fe, Ni (Co)	541	---	(Cr)
436	Au	---	542	---	Fe
437	---	Fe, Ni (Co)	545	---	(Co)
439	(Pb)	Fe	546	Ag	---
440	---	Au (Ag, Cr)	548	(Zn)	---
441	(Au)	(Cr)	550	---	Cr (Au)
442	(Au)	---	551	---	(Cr, Zn)
443	Au	(Cr)	552	---	Fe (Pb)
445	Au	---	554	---	Fe (Ni)
446	(B)	---	555	Pb	---

Appendix—Distribution of anomalously high concentrations of selected elements in stream-sediment and heavy-mineral-concentrate samples—Continued

	Element Anomalies				
Loc. No.	Sediments	Concentrates	Loc. No.	Sediments	Concentrates
557	---	Fe (Co)	648	(B)	Fe
558	---	(Cr, Zn)	649	Pb (Cu)	---
560	---	Cd (Cr, W, Zn)	658	---	Sn
562	(Cu, Mo)	(Mo)	659	(Au, Mn)	---
563	Cu, Mo	Mo, (W)	660	Mn	---
564	As, Cu, Mo (Ag,Be)	Mo, Sn (Bi, W)	661	Ag, Bi, Pb	---
565	(Cu, Sn)	Sn (W)	662	---	(Co)
566	Ag, Cu (Zn)	Mo, W)	663	(Au)	---
567	(Mn, Zn)	---	665	---	(Ni)
568	(B, Cu)	W	666	(B)	---
569	(B, Cu)	---	667	---	(Pb)
570	(B, Cu)	(Mo, Zn)	668	(Ba)	---
571	Ba	---	670	Au (Ba)	---
572	(B)	(Mo)	671	Ba	---
573	(B, Cu)	Fe (Zn)	672	Ba	---
574	Cu	---	675	Au	---
577	---	Cr	676	(Au)	---
581	---	(Cr)	679	Zn (Au, Be, Pb)	(Mo)
582	---	Sn	680	Pb, Zn	---
584	(Mn)	(Cr)	681	Zn	---
587	Sn	(Cr, W)	683	(Au)	---
588	---	Bi, Sn	684	---	Au, Mo (Cr)
589	(Sn)	Bi, Mo, Sn	685	---	Au (Ag)
590	(Be)	Be, Bi, Cd, Sn, Th, Zn	688	---	(Au)
591	---	(Au, Th)	689	(Pb, Zn)	(Pb)
592	---	(Cr)	690	Ag	(Au)
593	(Mn)	---	692	Zn	---
595	Bi, Mn, Sn, Zn	Sn (Bi)	693	(Pb)	Be
596	Zn (Mn, Sn)	---	695	Pb (Zn)	---
597	---	Sn, Be	696	(Zn)	---
598	Sn (B, Zn)	Sn (B, Be)	698	Pb, Zn	---
599	---	Sn (Au, B)	704	---	(Mo)
600	---	(Ag)	705	(Cu)	---
602	(Mn)	(Ag)	706	---	(B)
607	Au	---	707	(Mn)	(Mo)
608	(Au)	---	709	---	(Be)
609	Au	---	710	(Zn)	---
611	Ag, Au	---	711	---	(Ag, Pb)
614	---	(Co)	712	(Au)	---
615	Ba	---	713	(Au)	---
616	Zn	---	714	(Zn)	---
618	(Ba)	---	716	(Zn)	---
619	Cd, Mn, Mo, Zn	(Mo)	718	---	(Cu)
623	(Au, Ba)	(Mo)	719	---	As (Sb, Th)
624	Zn (Au)	---	720	(Zn)	---
625	B (Pb, Sn)	---	721	---	(Mo, Th)
626	(B)	Sb, Sn (Th)	723	---	(Mo)
627	(Ba)	(Au, W)	724	---	(Mo)
629	W	---	725	---	(Pb)
630	---	(Ag, Co, Pb)	726	---	(Mo)
632	---	(Co, Pb)	727	(Au, Mn)	(Mo)
634	(Pb)	(Co)	732	(Mn)	---
635	(Au)	---	733	Au	---
638	---	(Co)	736	(Mo)	(Au)
640	Au (Sn)	---	737	---	(Mo)
641	Pb (Mn, Zn)	---	738	Ag, Pb (Mn)	(Mo)
642	(Mn)	---	739	(Pb)	(Pb)
645	B	---	740	(Mn)	Mo, W
646	(Mn)	Fe	741	---	Pb
647	(Pb)	Fe	744	Zn	---

Appendix—Distribution of anomalously high concentrations of selected elements in stream-sediment and heavy-mineral-concentrate samples—Continued

Element Anomalies					
Loc. No.	Sediments	Concentrates	Loc. No.	Sediments	Concentrates
745	Mo (Zn)	---	857	(B)	Sn
746	As	As	858	(B)	Cd, Zn (Mo)
748	(Au, Cu)	---	859	(B)	Cr
750	---	Mo	860	---	Ag, B, Sb (Be, Cr)
752	(Mo)	---	861	(Au)	---
753	Mo, Zn (Ag, B)	---	862	---	Cd, Zn
755	(Au)	---	863	(B, Be)	Cd (Zn)
757	(Mn)	---	865	B (Be, Sn)	---
759	---	(Mo)	866	B, Be (Sn)	As (Au, W)
760	(Mn)	---	867	(B)	---
762	Mo (Ag, Zn)	(B)	868	(Au)	Sn
763	Ba (Au)	---	869	(Au)	Fe, As (Ag, Au, Bi)
764	(Mo)	---	870	Ag, As, Cu (Au,Pb)	Ag, As, Au, Co, Cu, Ni, Sb (Bi,Pb)
765	Mo	---	871	As, Au	Ag, As, Au, Bi, Co, Ni, Sb
766	(Mn)	---	872	(Mn)	---
768	(Ag, Ba, Mo)	---	873	(B)	(Au, W)
770	---	Ni (Cu, Th)	874	Ba	---
773	(Mn)	---	875	Ba (Cu)	---
774	(Mo)	---	876	Ba, Mn, Pb	---
775	(Mn)	---	877	Cu, Mn (Ba)	---
779	(Ba)	---	878	Mn, Zn (Ba)	---
787	(B)	---	879	Th	---
789	Sn (B, Mn)	---	882	---	Sn
790	Ba, Zn (Ag, Mo)	---	886	---	(Zn)
794	(Au, Pb)	---	887	---	(Zn)
796	Ba (Ag, Mo, Zn)	---	888	---	(Sb, Zn)
800	(Mn)	---	889	---	(Mo)
805	(Au)	---	891	---	(Au)
806	(Mn)	(B)	894	(Mn)	---
809	---	Be	896	(Mn)	---
815	(Zn)	---	897	(Be)	---
818	(Au, Pb)	---	898	(Be)	---
819	Pb	Fe	899	(Be)	---
820	---	Fe (Co)	900	(Be)	---
821	---	(Co, Ni)	901	(Be)	Mo, W (Au)
822	(B)	(Co)	902	Be	Sn
823	Pb	(Co, Ni)	903	Be	---
824	(B, Pb)	---	904	Be	Be
825	Pb	---	905	Be	(Bi)
826	(Pb)	(Ni)	906	(Be)	As, Sn (Ag, Au, Bi, Sb)
827	---	(Ag, Co, Pb)	907	Be (Pb)	Ag (Sb)
828	---	Pb (Ag, Bi)	908	Be (B)	Cd (Ag, Au, Zn)
829	(Pb)	(As, Pb)	909	(B)	---
833	---	(Au)	910	(B)	---
834	(Au)	(Ag, Au)	911	(Be)	---
836	---	(Th)	912	(Be)	---
837	Ba, Zn	As, Sn	913	Ag, Pb (Be)	(W)
838	Ba (Zn)	(Th)	914	Ag (Au, Be)	---
839	Au	---	915	Ag (Be)	Ag, Cd, Mo (Zn)
840	---	(Th)	916	Be	(Be)
843	(B)	---	918	---	Sn
846	(B)	---	919	---	Sn (B)
849	Cu, Mn, Zn (B)	Sb	920	(B)	---
850	(Cu)	---	921	(B)	---
851	Mn, Zn (B)	---	922	Sn (Be)	Sn
852	Zn (B, Cu, Mn)	---	923	---	Sn
853	---	(Sb)	924	B, Sn (Be)	B, Be, Sn (Bi)
854	(Zn)	---	925	(B)	---
855	(Zn)	---	926	---	(Ag, Au)
856	(B)	---	928	Au	---

Appendix—Distribution of anomalously high concentrations of selected elements in stream-sediment and heavy-mineral-concentrate samples—Continued

Loc. No.	Element Anomalies: Sediments	Element Anomalies: Concentrates
931	Mn	---
932	(Mn)	---
933	(B, Be)	Sn (Cu)
934	(B)	B
935	---	Sn (Sb)
936	Ag, Cu (B)	Sn (Ag, Bi)
937	(B, Be, Sn)	Sn (B, Bi)
938	(Be, Pb, Sn)	Sn
939	Be (Pb, Sn, Zn)	Sn (Bi, Mo, Th)
940	(Be)	---
941	(Be)	(Ag, Mo, Sb)
942	Ag, Pb, Sn (Be,Zn)	Ag, Cu, Mo, Pb, Sn
943	Be (Ag, Pb, Sn)	Be, Mo, Sn (Ag)
944	(Mn)	---
945	---	Ag, As, Au, Sn (Co)
946	---	Ag, Au
947	---	Ag, Sn (Au, Cr, Zn)
948	---	Cr
949	---	(Cr, Zn)
950	---	(Pb)
952	---	Ag, Co
954	---	(Ag, Bi, Ni, Pb, W)
955	---	(Ag, Au, Mo)
957	Pb	Fe
965	---	B
968	(Cd, Zn)	B
969	Cd (Zn)	---
970	---	Sn
973	---	(Au)
974	(Au)	---
977	B	B, Mo, Sn (Cr)
978	---	Cd
979	---	(Cr, W)
980	---	Cr
982	---	(Cu)
983	---	(Zn)
984	---	(Zn)
986	---	Cr (B)
987	---	(Cr)
988	---	Cr
990	(Zn)	Fe, Cd, Zn
993	---	Cd (Zn)
994	---	Fe (Zn)
995	---	Cd (Zn)
996	---	Zn (Be)
997	---	Fe, Co (As, Ni)
998	---	(Zn)
1000	---	Fe, Cd, Zn (Cu, Ni)
1002	Ba	---
1003	Ba, Cd, Mo (Ag,Zn)	---
1004	---	Sn (Be, Zn)
1005	(Pb)	---
1007	---	Cd (Zn)
1008	---	Fe, Cd (Zn)
1009	---	Fe (Zn)
1011	---	As (Sb)
1013	---	Cd, Zn
1014	As (Pb)	As, Pb (Ag)
1015	---	Pb (Sb)
1016	---	Fe, Ni (Pb, Sb)
1017	---	Fe (Co, Ni)
1018	As, Sb	Fe, As, Sb
1019	---	As, Sn
1020	---	Fe
1021	---	Fe, Co, Ni
1022	---	Fe (Co, Ni)
1024	---	Fe, Co (As)
1025	As	Fe, As, Cd, Co, Pb, Zn (Sb)
1026	---	Fe, Co (As, Cr, Pb, Zn)
1027	---	Cr (Ni, Th)
1028	---	Fe (As, B, Co)
1029	---	Cr
1030	As (Au)	Fe, As, Bi, Co, Ni, Sb (Au, Cu)
1031	As, Sb	---
1032	(B)	Cd, Pb, Zn (Ag)
1033	---	Cd
1034	Sb	---
1037	---	Cr
1038	---	(Cr)
1039	(Au)	Sn
1041	---	Cd
1042	(Au)	---
1044	Sb (Au, Sn)	Be
1045	As, B (Au, Sn)	As, B, Sn (Bi)
1046	As, Cd, Sb (Au,Sn)	---
1047	(Au, Sn)	Fe, As, Sb, Sn (W)
1048	B, Cd, Sn, W (Au)	As, Bi, Cr, Cu, Sn (Ag,Au,B,Be,W)
1049	(Au)	Fe, As, Cu
1050	(Au)	Fe, Ag, As, Au, Cu, Sb
1051	(Au)	Ag, As, Au, Sb
1052	(Au)	Fe, As, Au, Sb (Ag, Bi)
1053	(Au)	Fe, Cu, Pb, Sb (Ag, As)
1054	---	(As, Pb)
1056	Au	As, Sn (Au)
1057	Sb	Fe, Sb (Bi)
1058	---	(As, Bi)
1059	As, Pb (Au,Cd,Zn)	Fe (Ag, As, Sb)
1061	---	(Bi)
1062	Ag, As, Bi, Cd, Pb, Sb, W (Au,Ba,Cu,Zn)	Fe
1063	---	W
1064	---	Fe (Co)

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