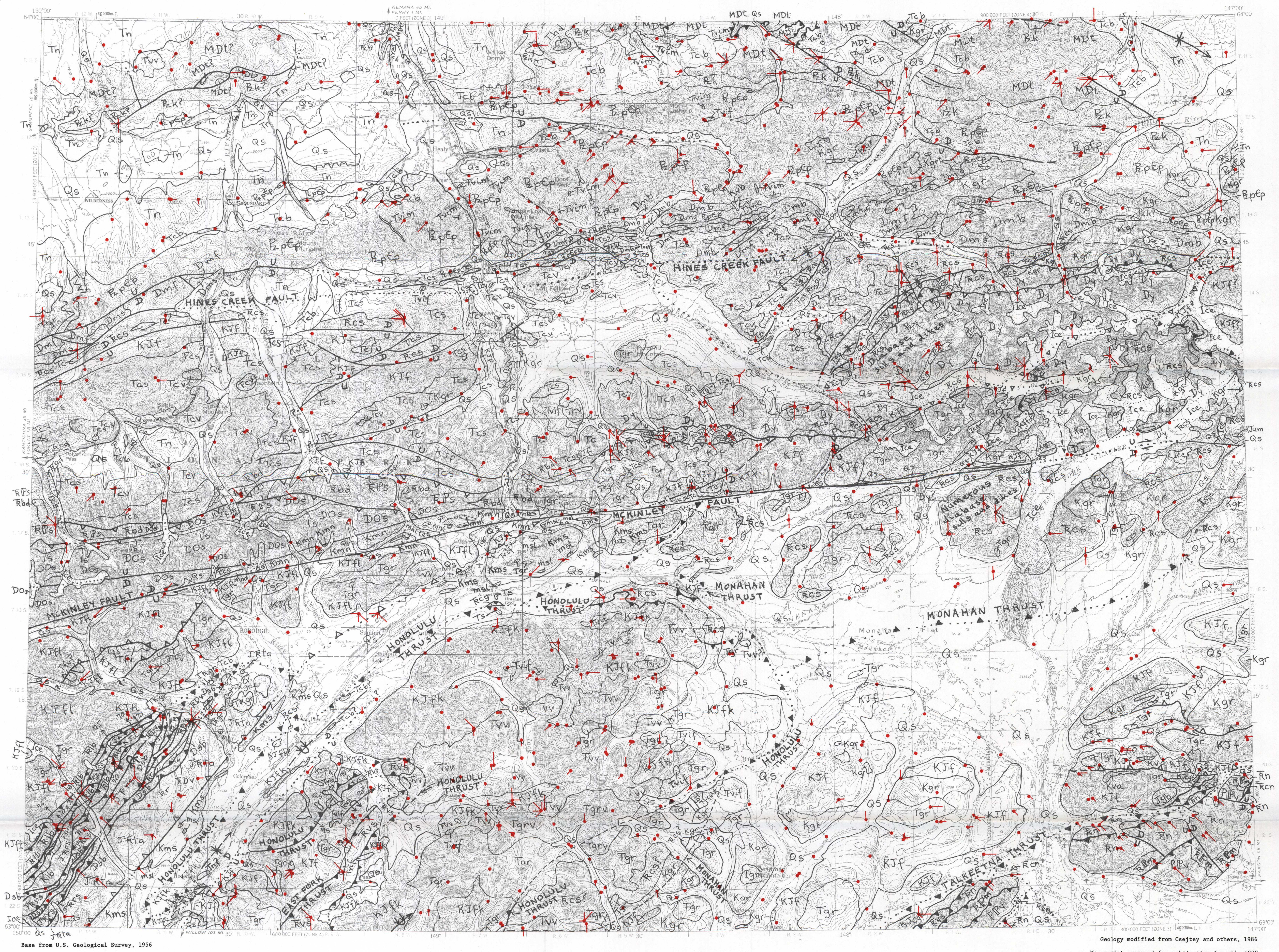
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY



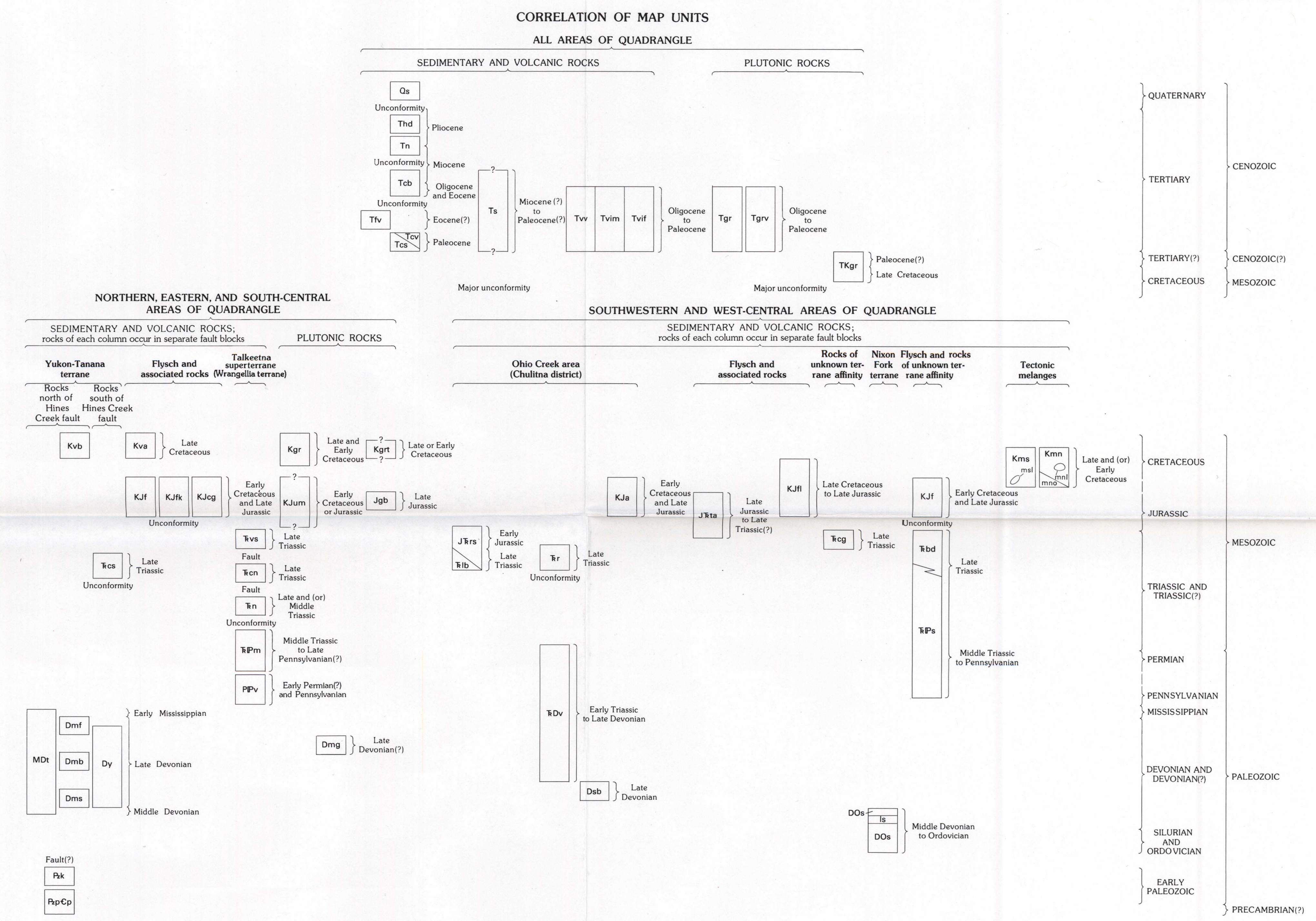



Base from U.S. Geological Survey, 1956

Geology modified from Csejtey and others, 1986

Manuscript approved for publication June 14, 1989

## CORRELATION OF MAP UNITS



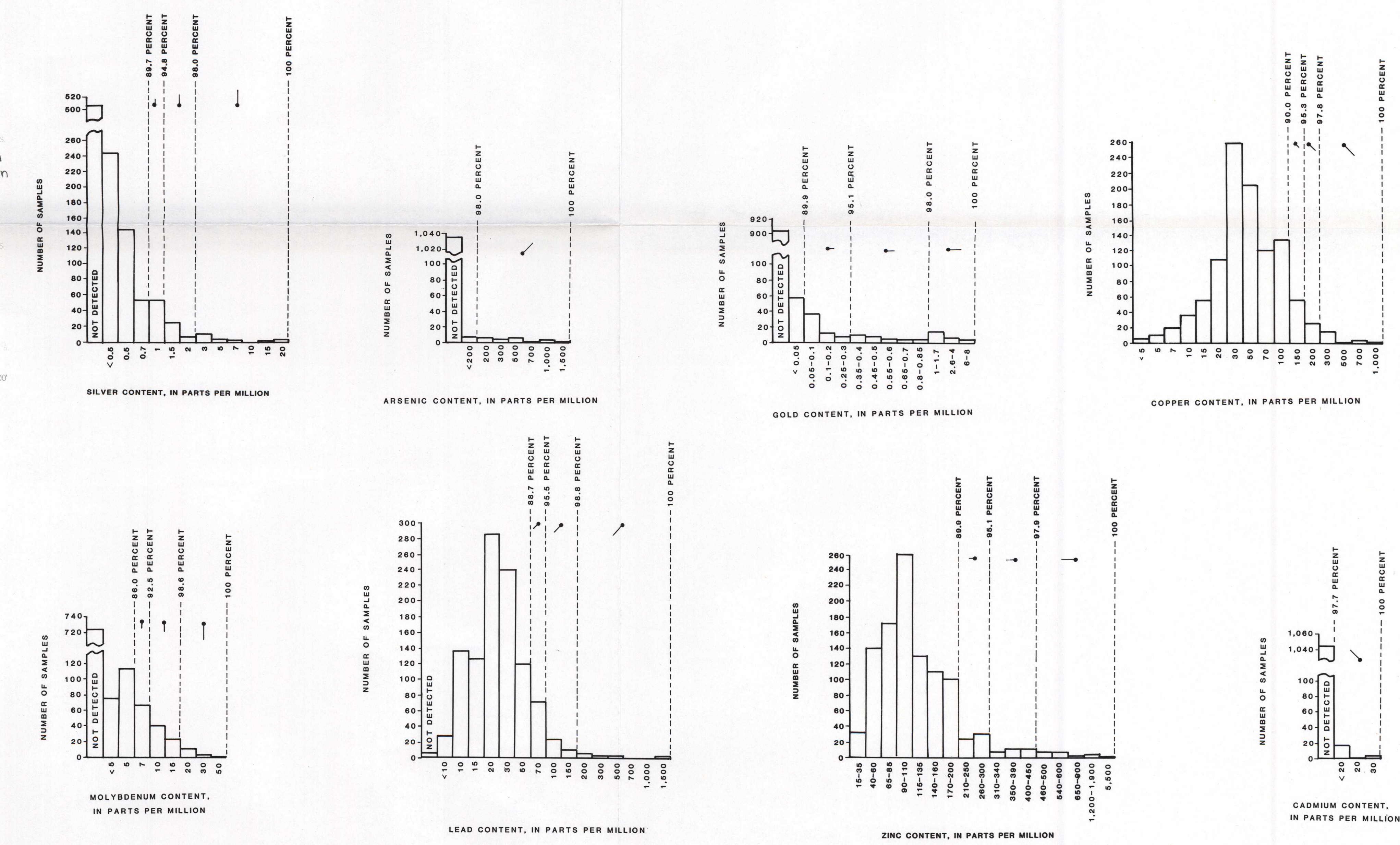
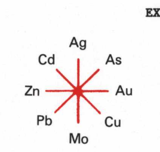




Figure 2.--Histograms showing concentrations of arsenic, cadmium, copper, gold, lead, molybdenum, silver, and zinc in 1,064 stream-sediment samples, Healy quadrangle. Vectors, which vary in length to denote concentrations or ranges of concentrations, correspond to symbols used on map A.

### EXPLANATION FOR GEOCHEMICAL SYMBOLS SHOWN ON MAP A




**Sample locality**--Showing vector diagram for selected elements in stream-sediment samples. Small round dot is sample locality; vector length indicates concentration for selected elements as explained in figure 2 for element whose chemical symbol is shown at outer end of vector. Vector length also indicates approximate percentile range as discussed in text and actual percentile range as shown in figure 2. No vector for a particular element at a sample site indicates that element was below the cutoff shown in figure 2.

SCALE 1:250 000

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
1956 MAGNETIC DECLINATION AT SOUTH EDGE OF SHEET VARIES FROM 26°30' TO 28°30' EAST

## MAP A.--ARSENIC, CADMIUM, COPPER, GOLD, LEAD, MOLYBDENUM, SILVER, AND ZINC

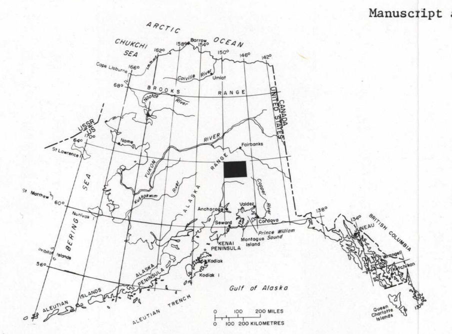


Figure 1.--Index map of Alaska showing location of report area.

## DESCRIPTION OF MAP UNITS

### ALL AREAS OF HEALY QUADRANGLE

SEDIMENTARY AND VOLCANIC ROCKS

- Qs — **Surficial deposits (Quaternary)**
- Thd — **Hornblende dacite (Pliocene)**
- Tn — **Nenana Gravel (Pliocene and Miocene)**--Poorly consolidated conglomerate and sandstone
- Tcb — **Coal-bearing rocks (Miocene to Eocene)**--Mainly siltstone and shale with subbituminous coal and lignite
- Ts — **Sedimentary rocks (Miocene? to Paleocene?)**--Mainly poorly consolidated shale, sandstone, siltstone, and conglomerate

**Volcanic rocks (Oligocene to Paleocene)**--

- Tvv — **Flows, pyroclastic rocks, and subvolcanic intrusions**--Subaerial volcanic rocks and subordinate dikes ranging in composition from basalt to rhyolite
- Tvim — **Felsic subvolcanic intrusive rocks**--Mainly dikes of rhyolite and dacite
- Tvif — **Mafic subvolcanic intrusive rocks**--Mainly dikes of basalt and subordinate andesite
- Tfv — **Fluviatile and volcanic rocks (Eocene?)**--Mainly conglomerate, sandstone, and siltstone and a few thin flows of basaltic andesite

**Cantwell Formation (Paleocene)**--

- Tcv — **Volcanic rocks subunit**--Flows of andesite, basalt, rhyolite, and dacite and pyroclastic felsic rocks
- Tcs — **Sedimentary rocks**--Mainly conglomerate, sandstone, and shale and a few thin coal beds and volcanic flows and tuffs

PLUTONIC ROCKS

- Tgr — **Granitic rocks (Oligocene to Paleocene)**--Mainly granite and granodiorite
- Tgrv — **Granitic and volcanic rocks, undivided (Oligocene to Paleocene)**--Border zone between granitic rocks and Tertiary volcanic rocks
- TKgr — **Granitic and hypabyssal intrusive rocks (Paleocene? and Late Cretaceous)**--Mainly granodiorite

### NORTHERN, EASTERN, AND SOUTH-CENTRAL AREAS OF QUADRANGLE

SEDIMENTARY AND VOLCANIC ROCKS

**Yukon-Tanana terrane**

Rocks north of Hines Creek fault

- Kvb — **Basaltic subvolcanic rocks (Late Cretaceous)**--Mainly dike swarms
- MDt — **Totatlanika Schist (Early Mississippian to Middle Devonian)**--Carbonaceous slate, phyllite, and schist; metachert, quartz-orthoclase-sericite schist and augen gneiss, metavolcanic rocks
- Dmf — **Felsic metavolcanic rocks (Late Devonian)**--Metamorphosed rhyolite and quartz latite
- Dmb — **Metabasalt and subordinate metasedimentary rocks (Late Devonian)**--Greenschist, metabasalt, and carbonaceous phyllite
- Dms — **Metasedimentary rocks (Late Devonian)**--Sericite schist, black slate, and chert
- Pzk — **Keevy Peak Formation (early Paleozoic)**--Mainly sericite schist, quartzite, arkosic schist, and black schist and phyllite
- Pz€p — **Pelitic and quartzose schist sequence (early Paleozoic and Precambrian?)**--Quartz sericite (carbonate) schist, quartzite, and black phyllite

Rocks south of Hines Creek fault

- Ŧcs — **Calcareous sedimentary rocks (Late Triassic; middle? Norian to late Karnian)**--Locally metamorphosed, carbonaceous, calcareous shale and sandstone and sandy to silty limestone. Includes sills and dikes of gabbro
- Dy — **Yanert Fork sequence (Late Devonian)**--Carbonaceous siliceous mudstone, slate, phyllite, and schist; impure quartzite and metachert, metavolcanic rocks, and marble interbeds. Also dikes and sills of gabbro

**Flysch and associated rocks**

- Kva — **Andesitic subvolcanic intrusive rocks (Late Cretaceous)**--Hornblende andesite
- KJf — **Flysch sequence (Early Cretaceous and Late Jurassic)**--Graywacke turbidite, shale, siltstone, and conglomerate Metamorphosed in southeast part of area.
- KJfk — **Overthrust flysch-like rocks (Early Cretaceous and Late Jurassic)**--Lithology identical to unit KJf
- KJcg — **Conglomerate, sandstone, siltstone, shale, and volcanic rocks (Early Cretaceous and Late Jurassic)**

**Talkeetna superterrane (includes Wrangellia terrane)**

- Ŧvs — **Metavolcanic, metavolcaniclastic, and subordinate metasedimentary rocks (Late Triassic; late Norian)**--Marine basalt, tuff, slate, and diabase sills.
- Ŧcn — **Chitistone and Nizina Limestones, undivided (Late Triassic; early Norian and late Karnian)**
- Ŧn — **Nikolai Greenstone (Late and (or) Middle Triassic)**--Mainly subaerial flows of amygdaloidal basalt
- Ŧℙm — **Metasedimentary rocks sequence (Middle Triassic to Late Pennsylvanian?)**--Black argillite, thin beds of volcanic breccia and sandstone, and limestone overlain by thin-bedded chert. Sills and dikes of gabbro
- Pℙv — **Andesitic volcanic rocks (Early Permian? and Pennsylvanian)**--Volcanic flows and breccias, probably marine

PLUTONIC ROCKS

- Kgr — **Granitic rocks (Late and (or) Early Cretaceous)**--Mainly tonalite, quartz diorite, and granodiorite, generally well foliated
- Kgrt — **Tourmaline-bearing granite (Late or Early Cretaceous)**
- KJum — **Ultramafic rocks (Early Cretaceous or Jurassic)**--Plagioclase-bearing peridotite
- Jgb — **Alkali gabbro (Late Jurassic)**
- Dmg — **Metagabbro (Late Devonian?)**

### SOUTHWESTERN AND WEST-CENTRAL AREAS OF QUADRANGLE

SEDIMENTARY AND VOLCANIC ROCKS

**Ohio Creek area (Chulitna district)**

- KJa — **Argillite, chert, sandstone, and limestone (Early Cretaceous and Late Jurassic)**
- JŦrs — **Red and brown sedimentary rocks and basalt (Early Jurassic and Late Triassic)**--Red sandstone, siltstone, conglomerate, and basalt overlain by brown sandstone and siltstone
- Ŧlb — **Limestone and basalt sequence (Late Triassic; Norian?)**
- Ŧr — **Red beds (Late Triassic)**--Red sandstone, siltstone, and conglomerate
- ŦDv — **Volcanogenic and sedimentary rocks (Early Triassic to Late Devonian)**--Tuffaceous chert, mudstone, and basalt breccia; flysch-like graywacke and mudstone; limestone
- Dsb — **Serpentinite, basalt, chert, and gabbro (Late Devonian)**

**Flysch and associated rocks**

- KJfl — **Flysch sequence (Late Cretaceous to Late Jurassic)**
- JŦta — **Crystal tuff, argillite, chert, graywacke, and limestone (Late Jurassic to Late Triassic?)**

**Rocks of unknown terrane affinity**

- Ŧcg — **Conglomerate and volcanic sandstone (Late Triassic; late Norian)**

**Nixon Fork terrane**

- DOs, ls — **Sedimentary rocks sequence (Middle Devonian to Ordovician)**--Black argillite and siltstone, massive limestone (ls), thinly bedded limestone, and chert

**Flysch and rocks of unknown terrane affinity**

- KJf — **Flysch sequence (Early Cretaceous and Late Jurassic)**--Same rocks as unit KJf in eastern and southern parts of quadrangle
- Ŧbd — **Basalt, diabase, and subordinate sedimentary rocks (Late Triassic; Karnian and Norian)**
- ŦℙPs — **Flysch-like sedimentary rocks (Late Triassic to Pennsylvanian)**--Impure sandstone, siltstone, and shale; minor limestone and chert

**Tectonic melanges**

- Kms, msl — **Melange south of McKinley fault (Late and (or) Early Cretaceous)**--Dark-gray flysch, cherty tuff, volcanic sandstone, and blocks of limestone (msl)
- Kmn, mnl, mno — **Melange north of McKinley fault (Late and (or) Early Cretaceous)**--Similar to unit Kms but contains recrystallized limestones (mnl) and ophiolitic rocks (mno), mainly serpentinite, basalt, and chert

- **Contact**--Approximately located
- **Thrust fault**--Showing direction of dip of overturned thrust fault. Dashed where inferred; dotted where concealed. Sawteeth on upper plate
- **High-angle reverse fault**--Dashed where inferred; dotted where concealed. Sawteeth on upper plate
- **Fault**--Dashed where inferred; dotted where concealed. Where displacement known, U, upthrown side, D, downthrown side; arrows indicate relative horizontal movement
- **Postulated position of fault prior to intrusion of plutonic and subvolcanic rocks**
- **Anticline**--Showing direction of plunge
- **Overturned anticline**--Showing direction of dip of limbs and plunge
- **Syncline**--Showing direction of plunge. Dashed where inferred
- **Overturned syncline**--Showing direction of dip of limbs and plunge. Dashed where inferred

### STUDIES RELATED TO AMRAP

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

### DISCUSSION

The U.S. Geological Survey conducted a reconnaissance geochemical survey of the Healy quadrangle, Alaska, between 1980 and 1982 as part of the Alaska Mineral Resource Assessment Program (AMRAP). The Healy quadrangle comprises approximately 6,400 sq mi in southern Alaska and includes the central Alaska Range and the eastern one-third of Denali National Park (fig. 1). The George Parks Highway is a major north-south access route across the western part of the area, and the Denali Highway crosses the south half of the quadrangle.

The Healy quadrangle lies along the accretionary continental margin of North America. Pre-accretion rocks of the ancient North American continent are exposed over large parts of the north half of the quadrangle and include schist, phyllite, and metavolcanic rocks of the Yukon-Tanana terrane. The south half of the quadrangle is underlain predominantly by a highly deformed and metamorphosed Jurassic-Cretaceous flysch sequence and several thrust sheets. The flysch sequence is interpreted to represent deposition in an oceanic basin between the converging Yukon-Tanana and Wrangellia terranes (Csejtey and others, 1982). The Wrangellia terrane is south of the Talkeetna thrust, in the southeast corner of the Healy quadrangle.

This study presents the univariate statistics (table 1), frequency distribution histograms (figs. 2 and 3), and a map plot showing the stream-sediment sample localities for which analytical values of selected elements exceed the 90th percentile of the sample population. Analytical data upon which this report is based were reported by O'Leary and others (1984). Interpretation of the geochemistry of the Healy quadrangle is presented in a U.S. Geological Survey Bulletin (Light and others, in press).

Stream-sediment samples represent rock material eroded from the drainage basin upstream from each sample site. Analysis of these samples can be used to define drainage basins that contain anomalous concentrations of elements that may be related to mineral deposits. Samples were collected from active alluvial material primarily from first-order (unbranched) and second-order (below the junction of two first-order) streams as shown on U.S. Geological Survey topographic maps (scale 1:63,360). Stream-sediment samples were collected from 1,064 sites in the Healy quadrangle for a sampling density of about one sample site per 6 sq mi.

Stream-sediment samples were dried and sieved at 80 mesh (0.18 mm) using stainless steel sieves. The minus-80-mesh (<0.18-mm) material was analyzed for 31 elements by a semiquantitative direct-current arc-emission spectrographic method (Grimes and Marranzino, 1968). Gold and zinc were also analyzed by atomic absorption methods (Ward and others, 1969). Analytical data were entered into the U.S. Geological Survey's Rock Analysis Storage System (RASS), a computer-based file, and were processed by the STATPAC program (VanTrump and Miesch, 1977).

This report shows the distribution of analytical values greater than the 90th percentile for Ag, As, Au, Cd, Cu, Mo, Pb, and Zn (map A) and for B, Ba, Co, Cr, Fe, Ni, Sn, and W (map B). A vector diagram is used to illustrate element concentrations and associations at each sample site. Variable ray lengths are used to distinguish sample localities for which analytical values fall within the 90th-95th percentile range (shortest ray), the 95th-98th percentile range, and the 98th-100th percentile range (longest ray). Because analytical data are given by a six-step reporting interval (except Au and Zn), percentile groupings vary somewhat. The actual percentile groupings and number of samples in each group are shown on the histogram plots for the respective elements (figs. 2 and 3).

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Table 1.--Statistical summary of analytical data for stream-sediment samples from the Healy quadrangle, Alaska

[Data are expressed in parts per million except for Fe, Mg, Ca, and Ti, which are in percent. aa, atomic absorption analysis; all other analyses by semiquantitative emission spectrography; dashes (--) denote no data; N, not detected; L and <, detected, but below the lower limit of determination; G and >, an undetermined amount greater than the upper limit of determination; qualified values, values modified by N, L, or G; unqualified values, values not modified by N, L, or G]

| Element | Minimum | Maximum | Arithmetic mean | Standard deviation | Geometric mean | Geometric deviation | Percentiles 90th | 95th | 98th | No. of qualified values N | L | G | Detection ratio[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fe | 0.7 | 15 | 4.3 | 2.1 | 3.8 | 1.7 | 7 | 7 | 10 | 0 | 0 | 0 | 1 |
| Mg | .1 | 10 | 1.2 | 0.91 | 0.96 | 1.9 | 2 | 3 | 3 | 0 | 0 | 0 | 1 |
| Ca | .05 | 10 | 1.2 | 1.5 | .67 | 3.1 | 3 | 5 | 5 | 0 | 3 | 0 | 1 |
| Ti | .03 | >1 | 0.5 | .25 | .48 | 1.8 | 1 | 1 | 1.5 | 0 | 0 | 51 | 0.95 |
| Mn | 100 | >5,000 | 965 | 609 | 804 | 1.9 | 1,500 | 2,000 | 3,000 | 0 | 0 | 1 | 1 |
| Ag | <.5 | 20 | 1.1 | 2.0 | .29 | 2.2 | 1 | 1.5 | 2 | 506 | 246 | 0 | .29 |
| As | <200 | 1,500 | 467 | 340 | <200 | 1.3 | <200 | <200 | <200 | 1,036 | 7 | 0 | .02 |
| Au | 10 | 15 | 12.5 | 3.5 | <10 | 1.1 | <10 | <10 | <10 | 1,062 | 0 | 0 | 0 |
| B | 10 | 1,000 | 83 | 66 | 65.4 | 2.1 | 150 | 150 | 200 | 0 | 1 | 0 | 1 |
| Ba | 70 | 5,000 | 1,068 | 704 | 922 | 1.8 | 1,500 | 2,000 | 5,000 | 0 | 0 | 7 | .99 |
| Be | <1 | 20 | 2 | 1.60 | 1.5 | 1.7 | 3 | 3 | 7 | 21 | 74 | 0 | .91 |
| Bi | <10 | 20 | 13 | 5.8 | <10 | 1.1 | <10 | <10 | <10 | 1,056 | 5 | 0 | 0 |
| Cd | <20 | 30 | 28 | 5.0 | <20 | 1.1 | <20 | <20 | <20 | 1,042 | 18 | 0 | 0 |
| Co | 5 | 150 | 25 | 14 | 21.6 | 1.7 | 50 | 50 | 70 | 4 | 2 | 0 | .99 |
| Cr | 10 | 3,000 | 200 | 232 | 143 | 2.2 | 300 | 500 | 700 | 0 | 2 | 0 | 1 |
| Cu | 5 | 1,000 | 63 | 76 | 43 | 2.4 | 100 | 150 | 300 | 0 | 6 | 0 | .99 |
| La | <20 | 700 | 65 | 54 | 44 | 2.2 | 100 | 150 | 200 | 49 | 35 | 0 | .92 |
| Mo | <5 | 50 | 8 | 5.1 | <5 | 2.0 | 7 | 10 | 15 | 725 | 76 | 0 | .25 |
| Nb | <20 | 70 | 22 | 7.2 | <20 | 1.6 | 20 | 20 | 30 | 559 | 367 | 0 | .13 |
| Ni | <5 | 300 | 67 | 43 | 52 | 2.1 | 100 | 150 | 150 | 1 | 4 | 0 | .99 |
| Pb | <10 | 1,500 | 35 | 60 | 25 | 2.1 | 70 | 70 | 150 | 6 | 29 | 0 | .97 |
| Sb | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1,064 | 0 | 0 | 0 |
| Sc | 5 | 70 | 22 | 12 | 19 | 1.6 | 30 | 50 | 50 | 1 | 0 | 0 | .99 |
| Sn | <10 | 300 | 40 | 55 | <10 | 1.6 | <10 | <10 | 20 | 997 | 18 | 0 | .05 |
| Sr | <100 | 1,000 | 252 | 174 | 168 | 2.2 | 500 | 500 | 700 | 72 | 82 | 0 | .86 |
| V | 20 | 700 | 170 | 88 | 151 | 1.7 | 300 | 300 | 500 | 0 | 0 | 0 | 1 |
| W | <50 | 70 | 55 | 10 | <50 | 1.1 | <50 | <50 | <50 | 1,041 | 19 | 0 | 0 |
| Y | 1 | 300 | 40 | 22 | 36 | 1.6 | 70 | 70 | 100 | 0 | 0 | 0 | 1 |
| Zn | <200 | 3,000 | 340 | 312 | <200 | 1.8 | 200 | 300 | 500 | 464 | 387 | 0 | .20 |
| Zr | 30 | >1,000 | 290 | 216 | 232 | 2.1 | 700 | 700 | 1,000 | 0 | 0 | 9 | .99 |
| Th | <100 | 200 | 150 | 58 | <100 | 1.2 | <100 | <100 | <100 | 1,044 | 16 | 0 | 0 |
| Au (aa) | <.05 | 8 | .75 | 1.2 | <.05 | 2.7 | .05 | .3 | .8 | 919 | 25 | 0 | .10 |
| Zn (aa) | 15 | 5,500 | 138 | 210 | 106 | 1.9 | 200 | 300 | 450 | 0 | 0 | 0 | 1 |

[1]Detection ratio = No. of determinations/divided by No. of samples analyzed.

# MAPS SHOWING DISTRIBUTION AND ABUNDANCE OF SELECTED ELEMENTS IN STREAM-SEDIMENT SAMPLES FROM A RECONNAISSANCE GEOCHEMICAL SURVEY OF THE HEALY QUADRANGLE, ALASKA

By
Harley D. King, Thomas D. Light, and Richard M. O'Leary

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