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Alaska Open-File Report 134

PRELIMINARY GEOLOGY OF THE MCGRATH-UPPER INNOKO RIVER AREA, WESTERN INTERIOR ALASKA

By

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ABSTRACT

The McGrath-upper Innoko River area contains a Late Paleozoic chert-argillite-limestone unit, Early(?) Cretaceous limy sandstone and impure limestone, and a thick section of mid- to Late Cretaceous lithic sandstone, siltstone, shale, and conglomerate. Late Cretaceous alkaline plutonic complexes, dike swarms, and associated mafic volcanics consisting of basalt, andesite, and minor tuffaceous sedimentary rocks intrude and overlie the bedded rocks. Glacial, eolian, alluvial, and colluvial deposits are abundant. Dominant structures are northeast-trending folds and high-angle faults.

Placer gold deposits have been mined from modern and older stream terraces in the Ophir mining precinct and the Candle Hills; total production is believed to be at least 500,000 ounces of gold. The gold placers in the Ophir area are found downslope and downstream from basaltic to rhyolitic dike swarms and are also concentrated along faults and dikes trending across the stream channels. The dike swarms contain anomalous amounts of gold, nickel, yttrium, chromium, and zirconium. Fractures in plutons and nearby hornfels zones locally contain anomalous amounts of base and precious metals which are probably the lode source of gold placers in the Candle Hills.

Analytical results of pan concentrates, stream sediments, and rock samples for 219 localities are shown.

INTRODUCTION AND ACKNOWLEDGMENTS

The Alaska Division of Geological and Geophysical Surveys has completed an inch-to-the-mile mapping and resource assessment of about 900 square miles in parts of the McGrath, Iditarod, and Ophir 1:250,000 Quadrangles of western interior Alaska (see map location on plate 1). This report is a preliminary release of geologic and geochemical data collected during 1977-79; work on the petrology and chemistry of the igneous and sedimentary rocks, on the mineralogy of pan concentrates, and on Quaternary deposits is still in progress.

The study area forms a part of the Kuskokwim Mountains, a low range of maturely dissected hills that span much of southwestern Alaska. Except for the Beaver Mountains, which have been carved and steepened by glacial ice, most of the region was not affected by late Quaternary glaciation. Elevation ranges from 320 feet on the Kuskokwim River to 4,150 feet in the Beaver Mountains. The layered sedimentary rocks form low rounded ridges that average 2,000 feet in elevation, whereas igneous complexes and associated hornfels form steep, rugged massifs that rise up to 1,500 feet above the surrounding hills.

About 80 percent of the study area is below timberline, and bedrock exposures are limited; however, some exceptionally good rock exposures can be found along stream bluffs and in the Beaver Mountains. Names different from those on U.S. Geological Survey map bases of streams and topographic features shown on plate 1 are corrections offered by local residents.

Ninety-four days were spent in the field; 9 in 1972, 22 in 1978, and 63 in 1979. Project geologist Thomas K. Bundtzen was assisted by Gregory M. Laird during three seasons and by Virginia F. Ferrell, Nicki D. Coursey, and Karen S. Emmel in 1979. Carol Allison (University of Alaska), C.J. Smiley

(University of Idaho), R.B. Blodgett (Oregon State University), and David L. Jones (U.S. Geological Survey) provided valuable information on plant and invertebrate fossil localities from the area (tables 1 and 2). Bruce Panuska (University of Alaska) collected paleocurrent information from the Cretaceous sedimentary rock section (table 3). Donald L. Turner and Barry Spell (University of Alaska Geophysical Institute) provided K-Ar age determinations from intrusive rocks (table 4). The Division of Geological and Geophysical Surveys Geochemical Laboratory analyzed rock, stream-sediment, and pan-concentrate samples (tables 5-8). Gold production figures from Ophir precinct and Candle Creek are shown in table 9. Robert B. Forbes provided selected uranium and thorium analyses from plutons (table 10). William S. Patton, Betsy Moll, and Robert M. Chapman (U.S. Geological Survey) offered helpful geological advice and comparisons to rocks they have studied in the Medfra Quadrangle immediately northeast of the project area.

The authors thank Toivo and Ron Rossander; Michael J. and Ellen O'Carroll; Warren, Lloyd, and Robert Magnuson; Roger Roberts; Philip Sayer; John Wortman; and Dave and Ann Miller, all long-time residents of the area, for informative discussions of past mineral activity in the Ophir mining district and on Candle Creek. The Rossander mining camp on Yankee Creek served as base camp for most of the 1979 field season. The authors also thank Gilbert R. Eakins and Wyatt G. Gilbert (Alaska Division of Geological and Geophysical Surveys) for reviewing this report.

SUMMARY OF GEOLOGY

Sedimentary Rocks

The oldest rock units recognized in the study area are small, discontinuous lenses and pods of banded tuffaceous chert, limestone, and quartz-rich sandstone (Pzlc, pl. 1) exposed in the core of a faulted, regional anticline east of Ganes Creek. Megafossils indicate a late Paleozoic age, and abundant radiolaria were collected that yield a 'probable' late Paleozoic age (table 2). Those lithologies are similar to the chert and limestone of Mississippian(?) age mapped by USGS geologists in the Medfra Quadrangle north of the study area (Patton and others, 1977).

Argillite, limy sandstone, and impure limestone (Klst, pl. 1) with conspicuous large Inoceramus sp? prisms exposed east of Spruce Creek are believed to be equivalent to a part of a quartz-carbonate sandstone and pebbly mudstone unit mapped by Patton and others (1980) in the Medfra Quadrangle, to which they assign an Early Cretaceous age (Hauterivian and Barremian).

The most abundant rock lithologies in the project area are lithic and sublithic shale, siltstone, sandstone, and conglomerate referred to by Cady and others (1955) as the Kuskokwim Group. During this study it has been divided into seven geologic units (Ksh, Kus, Kss, Kfss, Kcs, Kgs, and Klss, pl. 1) which represent lithologic units rather than a time-stratigraphic succession. In the project area the Kuskokwim Group is estimated to be about 7,000 feet (2,100 m) thick west and north of the Takotna River. The lower 1,500 feet (450 m) of the stratigraphic section consists of medium- to dark-gray, lithicrich, rhythmically layered, fine-grained sandstone, siltstone, and shale, and medium-grained channel sandstone that exhibits graded bedding, moderate sorting, wedging, and scour-and-fill structures believed to be formed by turbidity currents. Invertebrate fossils in this part of the section are uncommon and usually found in fragments as Inoceramus prisms. Trace fossils found in Yankee Creek (table 2, no. 7) have been reported from Mesozoic flysch sequences worldwide. The Kuskokwim Group ranges in age from late Early Cretaceous (Albian or younger) to Late Cretaceous.

Progressively higher in the section are increased amounts of flora-rich, medium- to coarse-grained sublithic sandstone, pebble sandstone, and conglomerate with locally large amounts of volcanic clasts. Near the top of the sequence, both west and east of Ganes Creek, are basaltic agglomerate and crystal tuff (Kac, pl. 1) and siliceous sandtone (Kgs, pl. 1); these units vary from 150 to 400 feet thick, serve as valuable marker beds, and represent the initiation of volcanism in Late Cretaceous time. Capping the section west of Ganes Creek is a limy sandstone rich in plant debris.

According to C.J. Smiley (written comm., January 1980), who examined plant fossils from localities throughout the Cretaceous sedimentary rock section:

> "None of the specimens are well enough preserved, nor complete enough, for specific identifications. Therefore, the age of your McGrath area deposits cannot be established from the available plant megafossils, other than to say that the dicot leaves indicate an age no older than Albian. The entire collection of rock samples with included plant debris seems to represent high-energy transport and rapid, sometimes turbulent deposition. The common occurrence of rounded wood chips suggests abrasion during transport. The representation of conifers as rare isolated needles shows a destruction of needled conifer shoots during transport. Similarly, the highly fragmented nature of the dicot leaves suggests short distance transport, probably in a turbulent medium, followed by rapid deposition. The samples containing the dicots most likely represent depositional sites nearer the shore than is indicated for the other samples."

The authors interpret the upper Lower to Upper(?) Cretaceous sedimentary section (fig. 1) as representing a deep sea-high energy basin or slope deposit (bottom of the section) that progressively filled with marginal prograding deltas in a shallow-marine near-shore environment (middle and upper part of the section). Initiation of volcanism near the top of the section may signify orogeny, uplift, and transition to a nonmarine(?) environment during early Late Cretaceous time.

Patton and others (1977, 1980) have provided strong evidence that the uppermost part of the Cretaceous sedimentary rock sequence on Fossil Mountain to the north is of nonmarine origin. However, conclusive evidence of nonmarine rocks within the area described in this report is lacking. Limited paleocurrent data (table 3) indicates a current flow to the west and southwest in the eastern part of the Cretaceous sedimentary basin.

Igneous Rocks

Intruding and overlying the sedimentary rocks are Late Cretaceous to Early Tertiary plutons, mafic extrusive piles, and complex dike swarms. Alkaline plutons composed of monzonite, syenite, and diorite (Km, Km-di, Ksy, Km-sy,

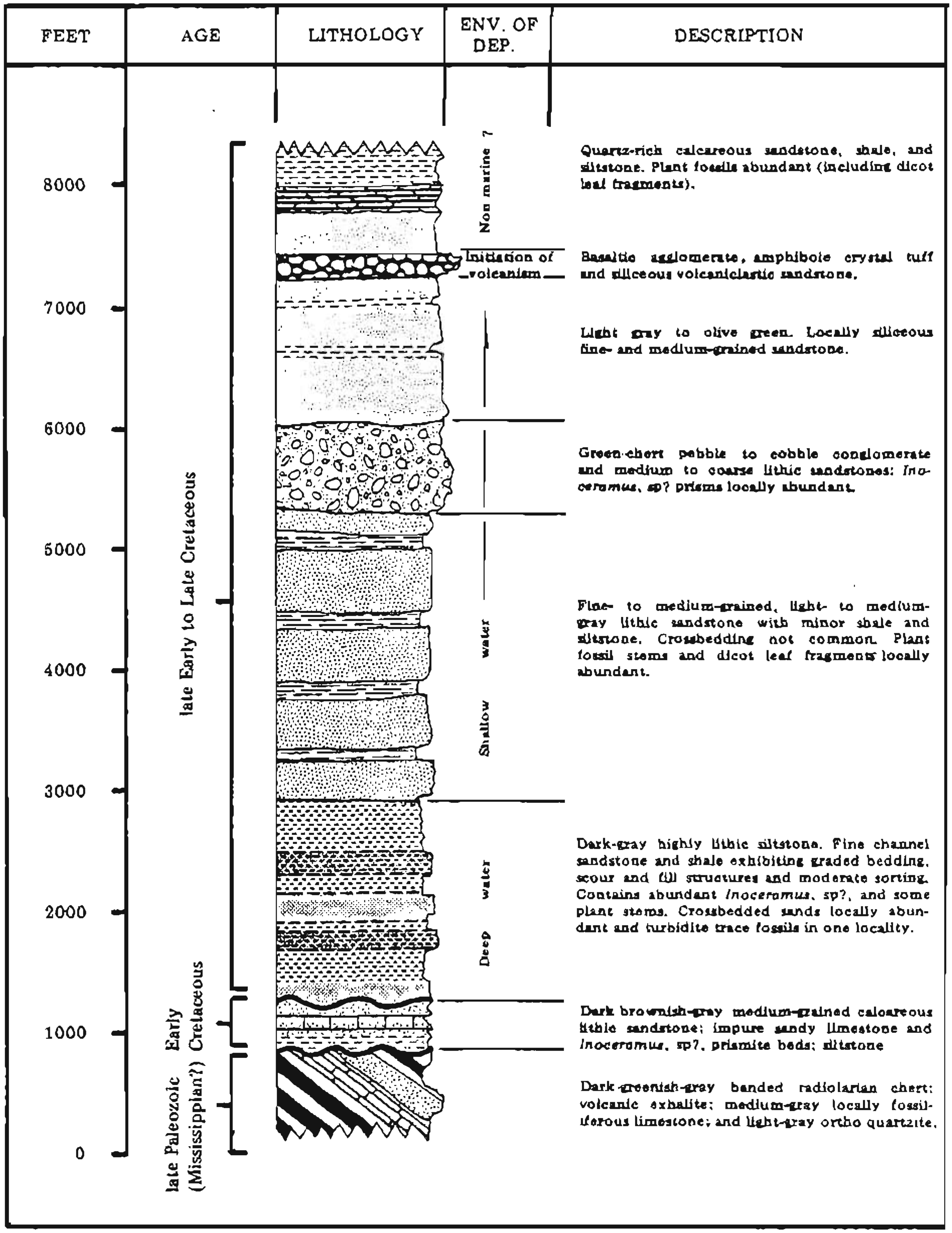

Figure 1. Composite stratigraphic section, Takotna-Ophir area, western interior Alaska

pl. 1) at Candle, Takotna Mountain, Mt. Joaquin, and in the Beaver Mountains are overlain by extrusive volcanic piles consisting of basalt and basaltic andesite (Kmv, Kpmv, pl. 1). Minor felsic volcanic flows, tuff, agglomerate, and tuffaceous sedimentary rocks are found in the Beaver Mountains volcanic section (Kfv, Kxt, Kua, Kvs, pl. 1). The volcanic-intrusive contact is at a very low angle both in the Beaver Mountains and at Candle, but appears to be locally a steep to vertical fault(?) contact at Takotna Mountain and Mt. Joaquin. Porphyroblasts of cordierite and chlorite developed in the overlying volcanic rocks of all three areas suggest that the alkaline plutons intrude the volcanic piles. Similar alkaline intrusive-extrusive complexes have been described at Page and Cloudy Mountains (Patton and others, 1980), near Flat (Mertie, 1936; Maloney, 1962) and at Goodnews Bay (Mertie, 1976). Numerous mafic to felsic dikes intrude the layered rocks along major shear zones or the axes of fold structures.

Quartz monzonite makes up parts of plutons west and south of Tatalina Mountain and in the Beaver Mountains. Five of six K-Ar mica ages from plutons and dikes in the project area average about 70 million years (table 4).

Thermally Altered Rocks

Hornfels aureoles up to several miles wide commonly rim the plutonic complexes (Khf, pl. 1). These consist of massive, dark-gray, locally porphyroblastic hornfels, baked argillite, and silicified sandtone, much of which is commonly difficult to distinguish from aphanitic mafic volcanic rocks. Locally, zones of intense brecciation mineralized with ferricrete gossan and manganiferous veining can be found, particularly near intrusive contacts. Hornfels often form distinctive topographic rims surrounding the plutons, especially in the Beaver Mountains. Volcanic rocks overlying intrusions at Takotna, Candle, Joaquin, and in the Beaver Mountains have undergone extensive thermal alteration locally but are not shown as hornfels (Khf) on plate 1.

Quaternary Units

The thirteen Quaternary units shown on plate 1 range in age from early(?) Pleistocene to Recent and consist of unconsolidated alluvium (Qal), placer-mine tailings (Qht), active and inactive sand-dune deposits (Qs, Qso), talus-cone and alluvial-fan deposits (Qt, Qaf), glacial drift deposits (Qdo, Qd, Qof, Qr), stream-terrace alluvium deposits of two ages (Qb, Qby), and undifferentiated Quaternary deposits (Qsu) that include windblown loess, retransported windblown materials, rock colluvium on hillslopes, and reworked glacial drift. Units in the Beaver Mountains and Ophir mining precinct were mapped by both photogeology and ground reconnaissance. In much of the remaining area, photogeologic techniques were used, and mapping and interpretation is still in progress. Quaternary deposits in the area record a complex history of uplift, localized glaciation in the Beaver Mountains (Bundtzen, 1980), and erosional processes in a periglacial environment.

Structure

The layered rocks have undergone two periods of folding, with the latest and apparently dominant deformation culminating in a series of northeast-trending anticlines and synclines with tight chevron-style fold axes. Major high-angle faults parallel the fold structure, the largest of which is the Nixon-Iditarod fault, a major strike-slip(?) feature in western Alaska (Grantz, 1966). Faults en echalon to this fracture include the Beaver Mountains fault and the Yankee-Ganes Creek fault (which is contained within a pervasive shear zone almost 1 mile wide). The emplacement of many of the plutons, volcanic rocks, and dike swarms is directly related to these major northeast-trending faults. Younger, less significant northwest-trending high-angle faults in the northwestern part of the map area have small left lateral displacements of a few hundred feet.

ECONOMIC GEOLOGY

Mining History

The Ophir mining precints and Candle Hills have had a substantial history of placer gold production from modern stream and older bench gravels. Earlier mining activities have been discussed by Eakin (1913), Maddren (1909, 1910, 1911), Mertie (1922, 1936), Mertie and Harrington (1924), and Wimmler (1922, 1926, 1929) and will only be summarized in a general way here.

Gold was first discovered in 1906 by a party of prospectors under the direction of Thomas Ganes, below the mouth of what became known as Ganes Creek. Rich placers were later discovered on Ophir Creek in 1908 and by 1910 discoveries had been made on Little, Ester, Yankee, Spruce, and Dodge Creeks. Gold in Anvil Creek remained untouched until 1917. The richest gold placers found in the project area were won from Candle Creek, first recognized and worked by Louis Blackburn and Bert Eldridge in 1913 (Mertie, 1936). Total gold production for the region is unknown but believed to have been at least 500,000 ounces (table 10).

Initially, deposits were mined by small-scale hydraulic operations and scraper plants (Mertie, 1936), but by 1920 a number of floating bucket-line dredges were brought into the district. These include the highly successful Kuskokwim Dredging Company dredge on Candle Creek (1919-26; 1949-51), the Flume Creek Dredging Company plants on Little and Yankee Creeks (which operated intermittently from 1922 through the mid-1930s), a dredge on lower Ganes Creek, and two dredges on Upper Ganes Creek which operated intermittently from 1924-1930 (one was later rebuilt by the Magnuson family and operated until 1960) (Jasper, 1959).

The Rossander-Reed dragline-dozer placer operation on Yankee Creek dominated gold mining activity and production in the Ophir precinct for nearly a quarter century following World War II.

Mining declined in the 1950s and 1960s as a result of the fixed price of gold ($35/ounce), but the industry has regained some of its former importance in the 1970s because of rising gold prices. Although gold production has fluctuated over the years, placer mining continues today on Anvil, Ophir, Spruce, Little, and Ganes Creeks, where modern mechanized placer miners use draglines, bulldozer tractors, and sluice boxes as recovery systems to remove overburden and process gold-bearing gravels.

Placer Deposits

Modern stream and older bench placer-gold deposits in the district have had a complex history due to regional uplift, the influence of glaciation in the Beaver Mountains, and erosion of mineralized bedrock in a periglacial environment.

Auriferous stream gravels in both modern stream and terrace alluvium average 8-15 feet thick in most placer-mine cuts in the district but occasionally exceed 30 feet in thickness. Overburden, which varies from 4 to 30 feet thick, is organic rich and commonly frozen. The gold-bearing paystreak is generally found in the last 18 inches of gravel and within the upper layers of the underlying weathered bedrock. This bedrock, for the most part, is fractured and weathered Cretaceous sandstone, siltstone, and shale (pl. 1), which placer miners 'rip' to a depth of 2-3 feet during removal of the gravel paystreaks in the sluicing process. Where dikes (Kd, Kfd, Kmd, Kid, pl. 1) cut these rocks, they form resistant ridges that protrude above the sedimentary layers and serve as effective mechanical riffles when they crosscut stream channels. In these instances heavy metals are often concentrated along the dike.

Bench gravels (terrace alluvium) have been successfully worked on Ophir, Spruce, Little, and Ganes Creeks. On these creeks the benches constituted some of the richest ground, and modern stream gravels were not worked until later years. In the early 1960s, a 62-ounce gold nugget, one of the largest found in Alaska in recent years, was recovered from bench deposits on Ganes Creek.

Yankee Creek is the best example in the district where gold-bearing paystreaks are mainly confined to shallow, modern stream gravels with minimal development of muck overburden.

Placer gold deposits in the Ophir mining precinct are concentrated along, downslope of, and downstream from structurally controlled dike swarms of basalt to rhyolite composition. The Candle Creek gold and heavy-mineral placers are derived from the adjacent monzonite and the overlying volcanic pile and probably represent residual accumulations of gold directly on an igneous bedrock source. Heavy-mineral placers in both the Candle Creek and Ophir precincts have not migrated far from lode sources and probably have been forming since late Tertiary time.

Gold fineness in the district varies from 835 to 910 and averages about 877, with virtually all of the impurities consisting of silver. Major heavy minerals contained in the stream concentrates besides gold include scheelite, cinnabar, garnet, tourmaline, and chromite. Mineralogical identification of heavy-mineral concentrates from past and present mining operations on Yankee and Spruce Creeks confirm the presence of chromite (table 9). Cinnabar, in particular, was so abundant in placer-mine concentrates on Anvil and Candle Creeks that some was recovered, retorted, and sold to local mine operators for mercury amalgum in earlier years (Maloney, 1962). Scheelite, the principal ore of tungsten, is particularly abundant in Little Creek concentrates (Mertie, 1936).

Lode Deposits

Mineral occurrences containing anomalous amounts of copper, lead, zinc, mercury, gold, silver, antimony, tungsten, nickel, chromium, yttrium, zirconium, and bismuth are found in the Candle Hills, Mt. Joaquin, the Beaver Mountains, and within the Ophir mining precinct. They include a fault-hosted mercury-arsenic-gold vein occurrence on Mt. Joaquin (188, pl. 2), copper-silver-bearing tourmaline greisen(?) veins along fractures in the Beaver Mountains (locs. 48, 54, 57, 58, pl. 2), mineralized copper-bearing hornfels and volcanic rocks at Candle and Takotna Mountains (locs. 199, 212, 207, 203, 204, 200, 181, 173, 174, pl. 2) and dikes throughout the area that contain anomalous amounts of gold, nickel, chromium, yttrium, and zirconium.

Several mineralized zones have been developed and explored by limited underground workings and trenching. The best known is the Independence Mine (fig. 2), developed during 1911-12 with a 60-foot-long tunnel, a 60-foot-long winze driven at its end, and drifts 50 feet and 30 feet long, respectively, at lower levels (Eakin, 1913). During the summer of 1912, 57 ounces of gold were milled from 125 tons of dike-hosted quartz carbonate vein material. A large trenched mineralized rhyolite dike on the divide between Spruce and Ester Creeks (fig. 3) also contains anomalous gold values as well as secondary oxides of antimony and arsenic. The Katz antimony lode described by Mertie (1922) near the head of Spaulding Creek was looked for but not found during geologic investigations. The Mt. Joaquin cinnabar-arsenopyrite-pyrite lode is a small fracture filling along a high-angle fault trending N. 10° W. across the top of Mt. Joaquin (loc. 188, pl. 2; pl. 1). Rubble indicates the mineralized zone extends for at least 200 feet along strike; however, no in-place exposures of sulfides were found.

Analyzed dikes at the heads of Ophir, Spruce, Little, Yankee, and Ganes Creeks contain anomalous concentrations of gold, chromium, and nickel. Nickel and chromium contents of the mafic dikes (Kmd, pl. 1) are three to five times the average crustal average for basaltic rocks (appendix 3). The gold anomalies appear to be confined to gossans developed within altered rhyolite and dacite dikes, whereas the high chromium and nickel values appear to be associated with mafic dikes and altered dikes of unknown composition (Kmd, Kid, pl. 1). The existence of high chrome values suggests that the mafic dikes are the source of the chromite found in the heavy mineral concentrates on Spruce and Yankee Creeks (table 9).

Limited results of uranium and thorium analyses from plutons in the project area (table 10) indicate that the alkaline rocks contain above- background concentrations of both radioactive elements. Ground traverses in the area with a Mount Sopris model SC131A scintillometer show that the layered sedimentary rocks average 120 cps, the volcanic rocks average 240 cps, and plutonic rocks vary from 180-400 cps. Recorded readings near intrusive-extrusive contact zones near the head of Candle Creek peaked at 550 cps in localized areas, but no radioactive minerals were identified.

Suggestions for Prospectors

Northeast-trending fault systems in the area control the distribution of many of the mineralized veins and igneous rocks thought to be the source of placer gold. Close examination and sampling of these fault zones and areas

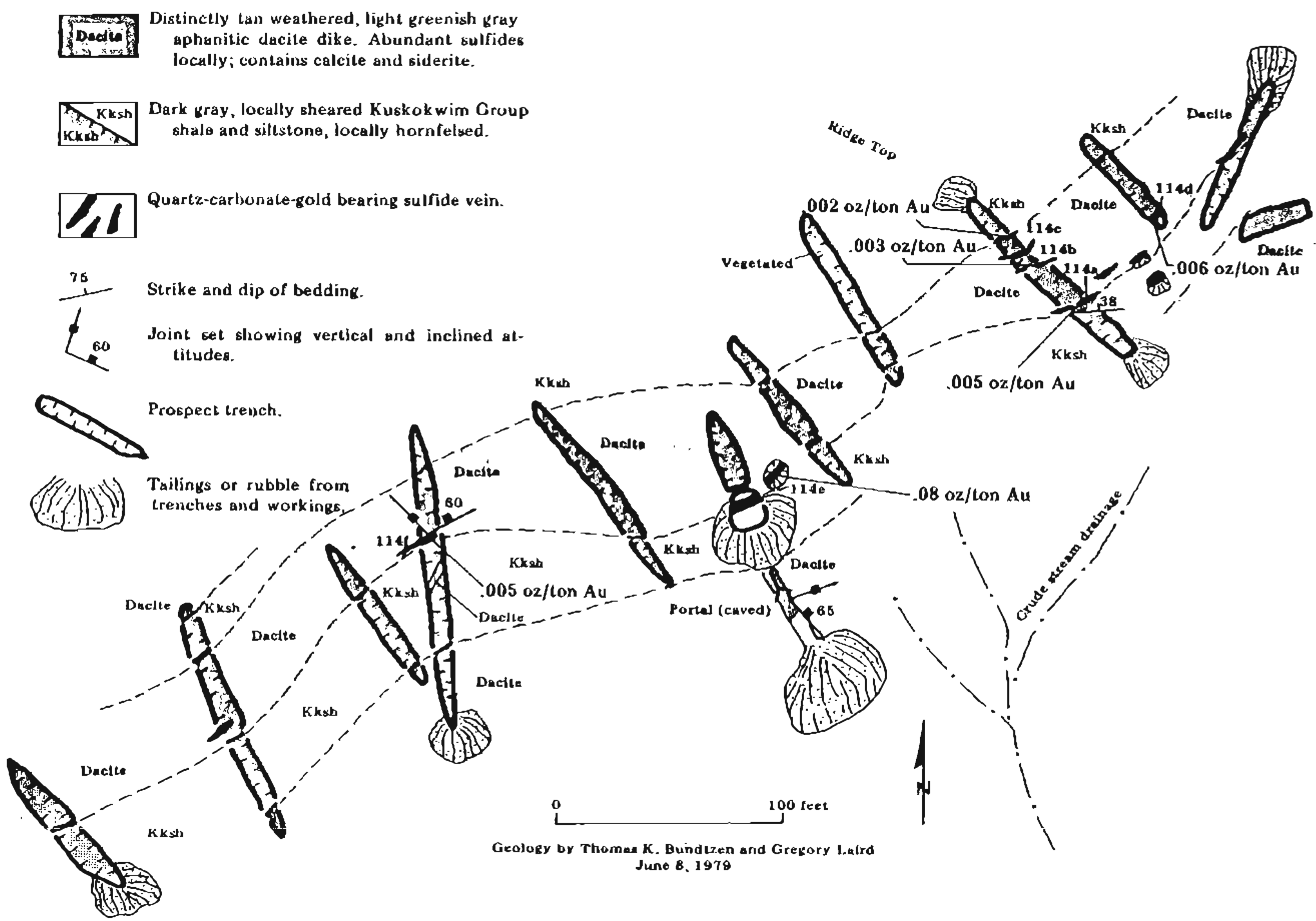

Figure 2. Geologic sketch map of the Independence Mine, Innoko mining district, Alaska

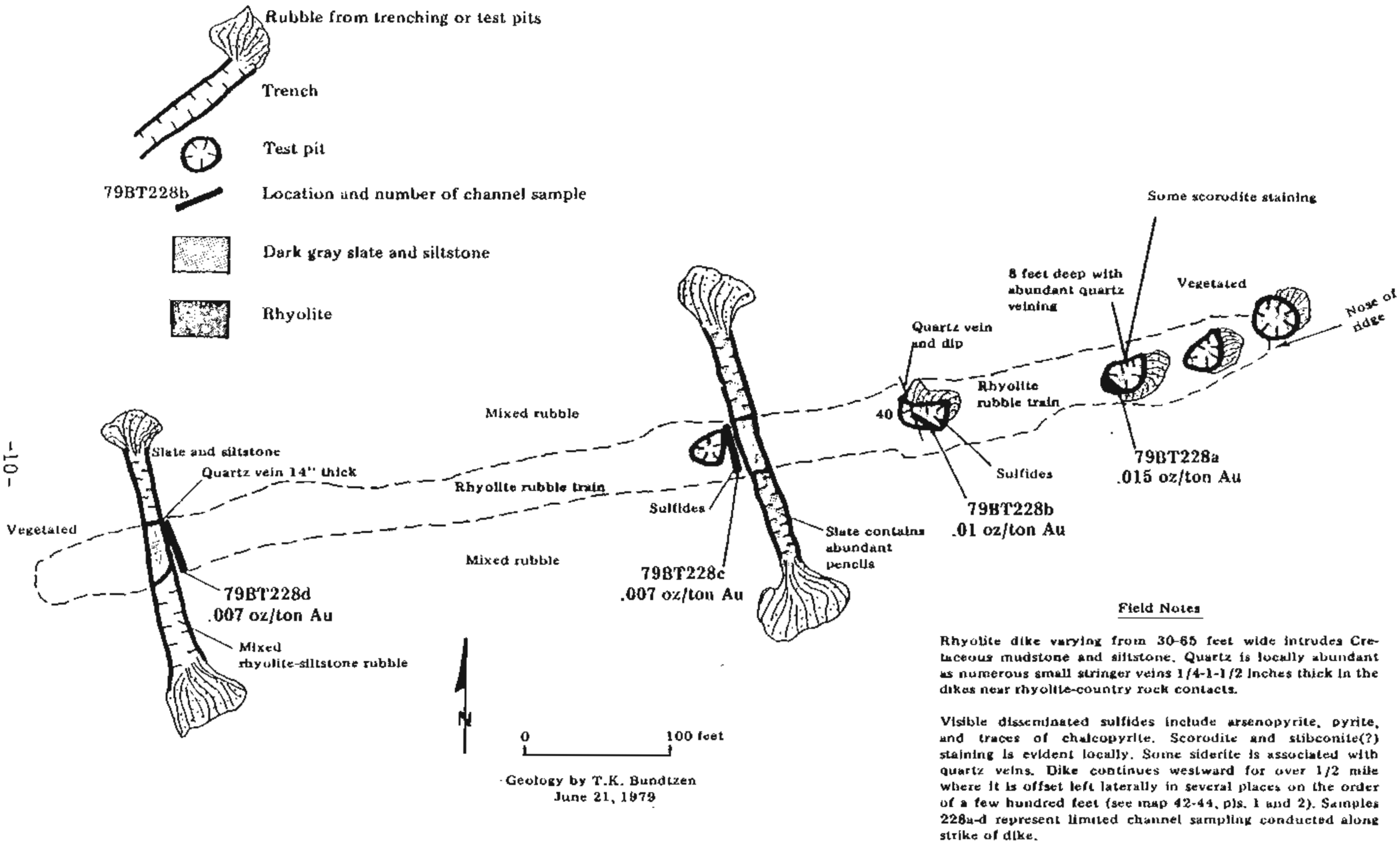

Figure 3. Geologic sketch of the Ester Creek rhyolite prospect, Innoko mining district, Alaska

downstream or downslope from them could lead to the discovery of placer and lode mineral deposits. Large yardages of auriferous benches may be present in unworked terrace alluvium in stream valleys of the Innoko precinct.

GEOCHEMISTRY

Analytical results of pan concentrates, stream sediments, and rock samples from 213 locations in the project area are shown in tables 5-7 and on plate 2. Appendixes 1-3 summarize sampling procedures and analytical techniques adopted during the geochemistry program. Anomalous values indicated in tables 6-8 and on plate 2 have been obtained from inspection of the raw data and comparisons to average crustal concentrations in basaltic, granitic, and sedimentary rocks (appendix 3).

Results of sampling seem to indicate that -80 mesh fractions of stream sediments may not be the optimum size range to use for geochemical exploration in the project area because creeks draining mineralized areas such as Candle Creek and near the Ganes-Yankee Creeks hydrologic divide do not yield the elemental anomalies that would be expected in the terrain investigated. At least three factors may be responsible for these results:

1) In many streams, alluvium has been reworked by placer miners.
2) Much of the -80 mesh fraction collected for analysis may be wind-blown loess and not derived from weathering and disintegration of nearby bedrock sources.
3) Extensive vegetation has inhibited the transportation of metal ions downslope into stream drainages.

Thus, pan concentrates may offer a better tool to understand heavy-mineral provenance of the stream systems in the region.

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Table 1. Preliminary descriptions of invertebrate fossil localities from sedimentary rocks, McGrath-upper Innoko River area.[a]

Map no. (field no.)	Approximate latitude and longitude; description of site	Description and remarks
1 (79BT335)	63°07'; 156°31' 1/2 mile north of Ophir, in Ophir A-2 Quadrangle, along north bank of Innoko River.	*Inoceramus* sp? pelecypod shell beds in Ksh unit, (pl. 1).
2 (79BT75)	63°05'; 156°32' 4 miles southwest of Ophir, in Ophir Creek in Ophir A-2 Quadrangle.	*Inoceramus* sp? pelecypod shell in shale-siltstone bed (Ksh, pl. 1).
3 (79BT231)	63°05'; 156°29' Ridgetop about 2 miles south of the mouth of Spruce Creek, Ophir A-1 Quadrangle.	Large *Inoceramus* sp? prisms up to 3 inches long and 1/4 inch thick in limy siltstone and limestone of Klst unit (pl. 1).
4 (79BT334)	63°06'; 156°40' On east bank of lower Beaver Creek 5 miles west-southwest of Ophir, Ophir A-2 Quadrangle.	*Inoceramus* sp? prisms in medium grained lithic sandstone of Kss unit (pl. 1).
5 (78BT458)	63°03'; 156°16' On east side of Takotna-Ophir road, 1-1/2 miles southeast from where Ready Bullion Creek crosses road in Ophir A-1 Quadrangle.	Three *Inoceramus* sp? pelecypod shells in Ksh unit (pl. 1).
6 (79BT232)	63°02'; 156°15' In Takotna-Ophir road cut just north of east-west trending gulch; in rubble.	Several fragments of *Inoceramus* sp? shells.

Table 1. (cont.)

Map no. (field no.)	Approximate latitude and longitude; description of site	Description and remarks
7[b,c] (78BT420)	63°01'; 156°21' About 1/3 mile south of Rossander mining camp, in bedrock drain at mouth of Marten Gulch.	Forms are similar to trace fossils reported from Mesozoic flysch deposits worldwide such as Helminthoidae (previously reported in Cretaceous rocks from Alaska); Helminthopsis, and Dendrothichnium (reported from Upper Cretaceous of Spain); Cormoraphe(?) and Slepchdeporitis(?) (reported from Cretaceous of Alaska) and Protopaleodictyon(?) (reported from North America flysch deposits of Mississippian to Tertiary age). Also a fragment resembling fish scales (recognized by the author); ID not determined.
8 (79BT156)	62°58'; 156°21' 1-1/2 miles west of Skookum Mountain along cat trail, Iditarod D-1 Quadrangle.	Inoceramus sp? fragment in siltstone of Kgs unit (pl. 1).
9[d] (79BT118)	62°57'; 156°28' On high ridgeline near divide between Ganes and Yankee Creeks, about 1 mile south of road.	Undetermined crinoid columnals and brachiopods in light-gray sandy limestone; radiolaria dissolved from chert yield upper Paleozoic Age.
10 (79BT183)	62°32'; 156°32' On ridgeline between Spaulding and Ganes Creeks, 2-1/2 miles south of 1979 Magnuson placer operation.	Radiolaria in chert; ID not now available.
11 (79BT96)	62°54'; 156°20' About 2-1/2 miles due south of fossil locality 8.	Inoceramus sp? prisms in coarse lithic sandstone of Kcs unit (pl. 1).
12 (79BT192)	62°58'; 156°10' 6 miles southwest of Takotna, Iditarod D-1 Quadrangle; in river cut.	Inoceramus sp? prisms in channel sandstone of Ksh unit (pl. 1).
13 (796F15)	62°59'; 156°05' 1 mile southwest of Takotna, Iditarod D-1 Quadrangle.	Two unidentified gastropods about 1/2 inch in diameter.

Table 1. (cont).

Map no. (field no.)	Approximate latitude and longitude; description of site	Description and remarks
14 (79BT59)	62°59'30"; 156°03' On west end of Takotna airstrip, Iditarod D-1 Quadrangle.	Numerous complete Inoceramus sp? shells, largest about 4 inches long; average about 1-1/2 inches in long dimension, in pelecypod-rich shale bed of Ksh unit (pl. 1).

[a]Preliminary identifications listed where available; more paleontological work in progress.
[b]Preliminary identifications by Dr. Carol C. Allison, University of Alaska Museum, Fairbanks, Alaska.
[c]Several specimens examined by Dr. C.J. Smiley, University of Idaho, Moscow, who relates, "The trace fossils at 78BT420 rise above the bedding surface and are forked rods that appear to be round in transect. Because of the forked branching pattern, I suspect that they were organic structures that fell onto the bedding surface, rather than being worm trails or borings."
[d]Preliminary age assignment by Dr. David C. Jones, U.S. Geological Survey, Menlo Park, CA.

Table 2. Cretaceous plant fossil identifications from McGrath-Upper Innoko River area[a]

Map no. (field no.)	Approximate latitude and longitude; description of collection site	Sample notes and remarks
1 (79G1F34)	63°10'; 156°33' Ophir Creek cut, west side; Ophir A-2 Quadrangle.	Medium-gray finely bedded sandstone with abundant small, flat wood chips on bedding surfaces. Some of the chips have rounded ends, probably caused by abrasion during transport.
2 (79BT314)	62°58'; 156°31' 3-1/2 miles west of Ganes Creek on knob at 2,000' ft. elevation, Iditarod D-2 Quadrangle.	Coarse, slabby calcareous sandstone with small wood chips and long, slender stems.
3 (79BT291)	62°54'; 156°34' In upper Ganes Creek Canyon, 3 miles upstream from 1979 placer operation on south wall.	Fine wood chips and a fragment of a dicot leaf occur in a black shaly coating of the curved surface of a thin sand lense. The dicot indicates that the Ksh unit is no older than Albian.
4 (79BT511)	62°47'; 156°45' On southwest ridgeline of Crater Mountain at 1,600 ft elevation, Iditarod D-2 Quadrangle.	Several fragments of dicot leaves (recognized by author) in a micaceous siltstone lens in Kss unit (pl. 1).
5 (79BT241)	62°54'; 156°33' On top of 2626 Mountain about 1-1/2 miles southwest of locality 6.	Dark-gray medium sand with abundant wood chips and plant stems.
6 (79BT240)	62°55'; 156°31' 2 miles east of the headwaters of Spaulding Creek, near top of 2262 Mountain.	Large three-dimensional wood chips in coarse sand plus several long, slender stems.
7 (79BT238)	62°56'; 156°31' About 3/4 miles north and 500 feet lower in the section from locality 6.	Medium gray sandstone with abundant plant material that has been broken up into small pieces. Fern? - could be the form Asplenium foersteri; dicot leaves - very common in fragments; conifer - rare isolated needles that may represent the Cretaceous form Cephalotaropsis heterophylla; wood chips - small pieces rounded by abrasion. The transporting medium seems to have been turbulent enough to break the dicot leaves into small fragments, but distance or duration of transport was evidently short; otherwise they would be completely destroyed.

Table 2. (cont.)

Map no. (field no.)	Approximate latitude and longitude; description of collection site	Sample notes and remarks
8 (79BT16)	62°59'; 156°25' 2 miles southwest of Rossander Gold camp, Yankee Creek, Iditarod D-1 Quadrangle.	Very small piece of silty sandstone contains a small, flat wood chip that appears to be rounded by abrasion.
9 (79BT157)	62°58'; 156°22' 1 mile east of junction between South Fork and Yankee Creek, Iditarod	Fairly "clean" medium sandstone with unidentifiable wood chips.
(79BT153)	Headwaters of S D-1 Quadrangle.	
11 (79BT148)	62°58'; 156°18' Headwaters of Ready Bullion Creek, Iditarod D-1 Quadrangle.	Gray medium-grained sandstone with a large, flat, carbonized wood stem.
12 (79BT232)	63°00'30"; 156°12' On Ophir road north of locality 13.	Rounded, flat wood chips in medium-grained sandstone.
13 (79BT231)	63°01'; 156°12' In Ophir road cut, Ophir A-1 Quadrangle.	Coarse to fine sands with distinctive flat bedding plane surfaces; fossils include a fragment of a dicot leaf and and large rounded wood chip almost 8 inches long.
14 (79BT38)	63°00'; 156°10' Headwaters of Canadian Creek on boundary of Ophir A-1 and Iditarod D-1 Quadrangle.	Long, narrow wood chips on bedding surface of medium-grained light-gray sandstone.
15 (78BT419)	62°58'; 156°08' At Takotna dump outcrop 1-1/2 miles southwest of Takotna.	Abundant organic plant debris in sheared and deformed lithic sandstone-siltstone section; lignitic mat is 1 inch thick but not examined in detail.

[a]Unless otherwise noted all identifications by Dr. C.J. Smiley, University of Idaho, Moscow.

Table 3. 25 Paleocurrent measurements collected from Cretaceous sedimentary rock units McGrath-Upper Innoko River area.[a]

Map no. (field no.)	Latitude and longitude; description of site	Azimuth (corrected for tile)(°)	Grand mean(°)	Standard deviation(σ)	Remarks
1 (79GL34)	63°06'; 156°35' About 5 miles southwest of Ophir on west bank of Ophir Creek, Ophir A-2 Quadrangle.	124 122 121 120 114 119 118 121 121	119.7	3.2	Statistically significant.
2 (79BT96)		234 237 240 229	235.0	3.0	Statistically significant (data collected by author).
3 (Takotna River)	About 62°57'; 156°11' on west bank of Takotna River, 3 miles southwest of Takotna, Iditarod D-1 Quadrangle.	266 266 260	264	3.5	Statistically significant.
4a (Takotna Dump A)	62°58'; 156°08' at Takotna Dump, 1-1/2 miles southwest of Takotna, Iditarod D-1 Quadrangle, Alaska.	274 292 299 279	286	11.5	Statistically significant.
4b (Takotna Dump B)	About 100 yards west of locality 4	213 228 54	207.5	109.6	Statistically random.
4A + B combined	- - -	- - -	272.5	66.7	Statistically random.

Table 3. (cont.)

Map no. (field no.)	Latitude and longitude; description of site	Azimuths (corrected for tilt)(°)	Grand mean(°)	Standard deviation(σ)	Remarks
5	62°51'; 156°11' at 1,100-ft elevation on ridgeline 4-1/2 miles southwest of Tatalina Air Force Station.	250 248	249	- - -	Statistically significant based on the two measurements available (collected by author).

[a]Except where otherwise noted all measurements collected and interpreted by Bruce Panuska, University of Alaska, Fairbanks. Measurements taken on striation casts, groove casts, flow casts and crossbeds.

Table 4. Analytical data for ^{40}K-^{40}Ar age determinations[a,b]

Field no. (sample no.)	Rock type	Mineral dated	K_2O (wt. %)	Sample weight (g)	$^{40}Ar_{rad}$ (moles/gm) x 10^{-11}	$^{40}Ar_{rad}$ / ^{40}K x 10^{-11}	$^{40}Ar_{rad}$ / $^{40}Ar_{total}$	Age $\pm$ 1σ (m.y.)
78BT-379 (79075)	monzonite	impure biotite	8.213 8.140 8.203 8.233 $\bar{x}$ = 8.197	0.1008	83.830	4.128	0.873	69.7 $\pm$ 2.1 (minimum age)
78BT-435 (79069)	monzonite	biotite	8.583 8.563 $\bar{x}$ = 8.573	0.1297	88.835	4.182	0.907	70.6 $\pm$ 2.1
78BT-461	monzo-diorite	impure biotite	8.883 8.880 8.880 8.857 $\bar{x}$ = 8.875	0.1117	92.802	4.220	0.900	71.2 $\pm$ 2.1
79BT-261	biotite quartz(?) monzonite	biotite	6.433 6.513 $\bar{x}$ = 6.473	0.1068	58.075	3.62	0.680	61.3 $\pm$ 1.8
9BT-301 80034	biotite dacite dike	biotite	7.097 7.050 $\bar{x}$ 7.074	0.1094	72.743	4.15	0.783	70.1 $\pm$ 2.1
79BT-436 80036	biotite rich syenite	biotite	8.753 8.743 $\bar{x}$ 8.748	0.1073	90.309	4.17	0.731	70.3 $\pm$ 2.1

[a]Constants used in age calculations: $\lambda_\epsilon = 0.585 \times 10^{-16}$ yr $^{-1}$
$\lambda_\beta = 4.72 \times 10^{-10}$ yr $^{-1}$
$^{40}K/K_{total} = 1.19 \times 10^{-4}$ mol/mol.

[b]Analyses by D.L. Turner and Berry Spell, Geophysical Institute, University of Alaska, Fairbanks.

Table 5. Analyses of stream-sediment samples (-80 mesh fraction) from the McGrath-upper Innoko River area (all results in ppm).[a]

Map no.	Field no.	Ag	Cu	Pb	Zn	Ni	Cr	Co	V	Zr
2	79BT1033S	ND	10	ND	ND	20	ND	NA	500	ND
3	79BT1031S	1.0	10	ND	ND	50	ND	NA	300	ND
4	79BT1032S	5.0	5	ND	ND	150	ND	NA	1,000	ND
5	79BT1038S	ND	10	ND	ND	20	ND	NA	300	ND
7	79BT1030S	5.0	15	ND	ND	150	ND	NA	700	ND
8	79BT1029S	1.0	10	ND	ND	30	ND	NA	300	ND
9	79BT1028S	ND	10	ND	ND	7	ND	NA	500	ND
10	79BT1044S	ND	10	ND	ND	10	ND	NA	300	ND
11	79BT1043S	1.0	10	ND	ND	10	20	NA	300	ND
12	79BT1045S	1.0	7	ND	ND	50	ND	NA	200	ND
13	79BT1046S	ND	5	ND	ND	10	ND	NA	300	ND
14	79BT1027A	1.0	10	ND	ND	50	ND	NA	300	ND
15	79BT1027S	2.0	10	ND	ND	20	ND	NA	1,500	ND
16	79BT1026S	3.0	10	ND	ND	100	ND	NA	1,000	ND
18	79BT76	2.0	15	ND	ND	20	ND	NA	300	ND
20	79BT77	1.0	10	ND	ND	20	ND	NA	300	ND
21	79BT78	1.0	10	ND	ND	30	ND	NA	300	ND
29	79BT221	1.0	10	ND	ND	20	ND	NA	300	ND
30	79BT222	ND	15	ND	ND	50	ND	NA	300	ND
31	79BT223	ND	7	ND	ND	30	ND	NA	300	ND
32	79BT224	ND	10	ND	ND	30	ND	NA	300	ND
33	79BT165	2.0	10	ND	ND	20	ND	NA	300	ND
45	79BT310	1.0	5	ND	ND	20	ND	NA	300	ND
49	79BT410S	5.0	20	ND	ND	100	ND	NA	1,000	ND
51	79BT411	1.0	10	ND	ND	10	20	NA	200	ND
64	79BT185	1.0	20	ND	ND	20	ND	NA	700	ND
72b	79BT138	2.0	5	ND	ND	15	ND	NA	200	ND
72a	79BT250	1.0	10	ND	ND	30	ND	NA	300	ND
73	79BT137	1.0	5	ND	ND	10	ND	NA	300	ND
74	79BT139	ND	15	ND	ND	10	20	NA	500	ND
75	79BT252	ND	10	ND	ND	20	ND	NA	200	ND
76	79BT251	1.0	15	ND	ND	20	ND	NA	300	ND
77	79GF7	1.0	10	ND	ND	20	ND	NA	700	ND
78	79GF8	ND	10	ND	ND	30	ND	NA	200	ND
81	79BT1025S	1.0	10	ND	ND	20	ND	NA	300	ND
82	79BT1023S	ND	10	ND	ND	15	ND	NA	500	ND
83	79BT1024S	1.0	10	ND	ND	10	ND	NA	500	ND
85	79BT1021S	2.0	10	ND	ND	20	ND	NA	500	ND
86	79BT1022S	1.0	10	ND	ND	70	ND	NA	500	ND
95	79BT107	ND	10	ND	ND	20	20	NA	200	ND
96	79BT106	1.0	10	ND	ND	20	20	NA	300	ND
99	79BT1004A	1.0	10	ND	ND	30	ND	NA	300	ND
100	79BT1005S	5.0	10	ND	ND	10	ND	NA	500	ND
101	79BT1001S	3.0	10	ND	ND	20	ND	NA	300	ND
102	79BT1006S	1.0	10	ND	ND	10	ND	NA	300	ND
103	79BT1004B	ND	20	ND	ND	50	ND	NA	300	ND
104	79BT1003S	1.0	10	ND	ND	30	ND	NA	200	ND
108	79BT31	ND	10	ND	ND	30	ND	NA	NA	ND

Table 5. (cont.)

Map no.	Field no.	Ag	Cu	Pb	Zn	Ni	Cr	Co	V	Zr
112	79BT1002S	ND	5	ND	ND	30	ND	NA	200	ND
113	79BT1001S	2.0	10	ND	ND	10	ND	NA	500	ND
117	79BT24	1.0	10	ND	ND	10	ND	NA	300	ND
118	79BT25	1.0	15	ND	ND	50	ND	NA	300	ND
120	79BT1000S	5.0	10	ND	ND	20	ND	NA	500	ND
121	79BT1034S	ND	15	ND	ND	20	ND	NA	500	ND
122	79BT1035S	7.0	20	ND	ND	100	ND	NA	1,000	ND
123	79BT1037A	ND	7	ND	ND	30	ND	NA	300	ND
125	79BT1036S	2.0	15	ND	ND	10	ND	NA	500	ND
126	79GL32S	1.0	10	ND	ND	20	ND	NA	300	ND
128	79BT1042S	ND	5	ND	ND	50	ND	NA	300	ND
129	79BT1040S	ND	10	ND	ND	30	1,000	NA	300	ND
130	79BT1020S	ND	5	ND	ND	10	ND	NA	200	ND
133	79BT1011S	3.0	10	ND	ND	20	ND	NA	700	ND
134	79BT1008S	1.0	10	ND	ND	10	ND	NA	300	ND
135	79BT1010S	1.0	5	ND	ND	15	ND	NA	300	ND
136	79BT1009S	2.0	5	ND	ND	20	ND	NA	200	ND
137	79BT1019S	1.0	5	ND	ND	20	ND	NA	200	ND
138	78BT406	0.5	21	16	101	5	ND	10	200	ND
139	78BT405	0.5	23	17	93	7	20	20	200	ND
140	79BT1018S	ND	7	ND	ND	50	ND	NA	300	ND
141	79BT1017S	1.0	7	ND	ND	5	ND	NA	300	ND
142	79BT1016S	2.0	10	ND	ND	20	ND	NA	500	ND
143	79BT1015S	ND	5	ND	ND	20	ND	NA	200	ND
144	79BT1014S	1.0	15	ND	ND	20	ND	NA	300	ND
145	79BT1013S	1.0	15	ND	ND	20	ND	NA	300	ND
148	79BT147	ND	10	ND	ND	20	ND	NA	300	ND
149	79BT146	2.0	20	ND	ND	20	ND	NA	500	ND
150	79BT216	2.0	7	ND	ND	20	ND	NA	500	ND
152	79GL16	2.0	15	ND	ND	20	ND	NA	300	ND
153	79GL17	1.0	10	ND	ND	100	ND	NA	200	ND
154	79BT51	2.0	10	ND	ND	20	ND	NA	300	ND
155	79BT50	1.0	7	ND	ND	20	ND	NA	150	ND
156	79BT48	1.0	10	ND	ND	20	ND	NA	200	ND
157	79BT46	1.0	15	ND	ND	50	ND	NA	300	ND
159	79BT60	1.0	10	ND	ND	50	ND	NA	300	ND
160	79BT61	ND	10	ND	ND	20	ND	NA	300	ND
161	79GL195	5.0	15	ND	ND	150	ND	NA	500	ND
162	79BT1012S	5.0	10	ND	ND	10	ND	NA	500	ND
164	79BT207	5.0	15	ND	ND	70	ND	NA	1,000	ND
167	79BT201	10.0	15	ND	ND	50	ND	NA	500	ND
168	79BT192	5.0	20	ND	ND	100	ND	NA	700	ND
169	79BT191	3.0	10	ND	ND	20	ND	NA	1,000	ND
170	78BT395	0.7	25	22	68	50	ND	10	200	200
171	78BT469	0.6	33	20	68	20	50	10	300	500
172	78BT470	0.6	100	50	80	20	20	20	200	ND
180	78BT421	0.4	46	19	80	20	20	20	500	ND
182	78BT422	0.8	43	26	72	20	ND	10	200	ND
183	78BT425	0.4	23	13	91	50	20	10	300	200
185	79BT249	ND	5	ND	ND	10	ND	ND	200	ND

Table 5. (cont.)

Map no.	Field no.	Ag	Cu	Pb	Zn	Ni	Cr	Co	V	Zr
186	79BT1055S	ND	5	ND	ND	5	ND	ND	200	ND
189	78BT447	0.8	48	22	74	50	50	20	300	ND
190	79BT1051	ND	10	ND	ND	20	ND	NA	200	ND
191	79BT1052	ND	5	ND	ND	10	ND	NA	200	ND
192	79BT1048	ND	20	ND	ND	15	ND	NA	200	ND
194	79BT1047	2.0	10	ND	ND	50	ND	NA	300	ND
195	79BT283	1.0	10	ND	ND	50	ND	NA	300	ND
196	79BT1053	1.0	5	ND	ND	20	ND	NA	300	ND
197	79BT284	ND	5	ND	ND	10	ND	NA	200	ND
198	79BT1054	1.0	10	ND	ND	30	ND	NA	300	ND
208	77BT236	0.5	42	16	95	25	NA	NA	NA	NA
209	77BT235b	0.4	32	77	72	23	NA	NA	NA	NA
211	78BT370	0.4	26	14	67	50	ND	10	200	200
215	77BT251	0.4	22	ND	72	30	NA	NA	NA	NA
216	77BT241	0.4	24	1	75	33	NA	NA	NA	NA
217	77BT240	0.5	25	7	86	35	NA	NA	NA	NA
218	77BT231	0.4	25	27	68	28	NA	NA	NA	NA

[a]Analytical work by Michael R. Ashwell and Namok C. Veach, DGGS Minerals Laboratory. Cu, Pb, Zn, Ag, and Ni in 1977 and 1978 samples (see field-number prefix) analyzed by atomic absorbtion spectrophotometry. All remaining elements in 1978 and 1979 samples analyzed by emission spectrography. Be, Sn, Mo, Nb, W, Sb, Y, Bi, and Au were below the limits of detection in all stream-sediment samples. NA = not analyzed. ND - not detected. For limits of detection and analytical procedure data, see appendixes 1 and 2; underlined values are considered anomalous. Silver values of less than 10 ppm and vanadium anomalies (underlined) are considered questionable by the authors.

Table 6. Analyses of rock samples from the McGrath-upper Innoko River area (all results in ppm).[a]

Map no.	Field no.	Au	Ag	Cu	Pb	Zn	Ni	Cr	Co	W	V	Sb	Y	Bi	Zr	Remarks
1	79BT333	ND	2.0	100	ND	ND	500	1,000	ND	ND	300	ND	ND	ND	ND	Altered mafic dike.
6	79BT160	0.35	ND	15	ND	ND	15	ND	NA	ND	150	ND	ND	ND	ND	Quartz-vein gossan near dike.
17	79CL47	0.03	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Mineralized dike.
19	79BT84	0.00	ND	20	ND	ND	20	ND	ND	ND	70	ND	ND	ND	ND	Quartz-vein chip sample.
22	79BT77R	0.00	ND	100	ND	ND	20	ND	ND	ND	500	ND	ND	ND	ND	Sulfide-bearing dacite dike.
23	79CL42	0.02	5.0	100	ND	ND	100	1,000	ND	ND	500	ND	ND	ND	ND	Quartz-vein gossan in mafic dike swarm.
24	79BT79R	0.01	3.0	100	ND	ND	20	20	ND	ND	1,000	ND	ND	ND	ND	Mineralized(?) dike.
25	79CL35	0.03	10.0	500	ND	ND	10	20	ND	ND	300	ND	ND	ND	ND	Mineralized dike(?).
26	79CL36	0.01	5.0	50	ND	ND	100	700	ND	ND	500	ND	ND	ND	ND	Fresh dacite(?) dike.
27	79BT85	0.00	5.0	70	ND	ND	50	150	ND	ND	500	ND	ND	ND	ND	Quartz-vein chip sample.
28	79BT86	0.00	7.0	100	20	ND	500	1,000	ND	100	300	ND	ND	ND	ND	Mafic-dike chip sample.
34	79BT169	0.02	ND	100	ND	ND	30	6	ND	ND	200	ND	ND	ND	ND	Quartz vein in dike.
35	79BT171	0.87	5.0	70	ND	ND	200	500	ND	ND	500	ND	100	ND	ND	Slate- and sulfide-bearing dike; chip sample.
36	79BT174	0.40	ND	70	ND	ND	50	ND	ND	ND	150	ND	ND	ND	ND	Iron-carbonate quartz vein.
37	79BT172	0.23	5.0	70	ND	ND	20	200	ND	ND	1,500	ND	ND	ND	ND	Pyrrhotite-bearing dike.
38	79BT173	0.02	ND	ND	ND	ND	20	ND	ND	ND	200	ND	ND	ND	ND	Sulfide-bearing dike.
39	79BT227	0.01	ND	100	ND	ND	100	20	ND	ND	200	ND	ND	ND	ND	Quartz vein in sandstone.
40	79BT228A	0.52	ND	50	ND	ND	5	ND	ND	ND	300	ND	ND	ND	ND	40-41 series are composite grab
	79BT228B	0.31	ND	50	ND	ND	20	ND	ND	ND	200	ND	ND	ND	ND	samples along 150 meters of strike
41	79BT228C	0.26	ND	50	ND	ND	20	ND	ND	ND	200	ND	ND	ND	ND	length of a trenched mineralized
	79BT228D	0.24	ND	70	ND	ND	50	ND	ND	ND	150	ND	ND	ND	ND	rhyolite dike.
42	79BT303	0.63	5.0	50	ND	ND	20	ND	ND	ND	200	ND	ND	ND	ND	Samples 42-44 are composite grab
43	79BT302a	0.00	ND	100	ND	ND	70	ND	ND	ND	150	ND	ND	ND	ND	samples along 200 meters of the
	797BT302b	0.25	ND	15	ND	ND	35	ND	ND	ND	500	ND	ND	ND	ND	western limit of the mineralized
44	79BT302	0.78	ND	70	ND	ND	20	ND	ND	ND	200	ND	ND	ND	ND	dike in the 40-41 samples.
46	79BT451	0.01	50.0	500	ND	1,000	15	ND	ND	ND	100	ND	ND	ND	300	Mineralized hornfels.
47	79BT420	0.00	7.0	150	ND	200	5	ND	ND	ND	200	ND	ND	ND	ND	Gossan in monzonite.
48	79BT403	0.10	30.0	1,000	70	200	20	ND	NA	ND	30	100	ND	ND	200	Mineralized monzonite; also contains 20 ppm Mo.
50	79BT410R	0.02	5.0	70	ND	ND	20	20	NA	ND	500	ND	ND	ND	ND	Gossanized monzonite-diorite grab sample.
52	79CL303R	0.01	ND	150	ND	ND	10	ND	NA	ND	150	ND	ND	ND	ND	Quartz-vein gossan.
53	79CL304R	0.01	5.0	20	ND	ND	50	ND	NA	ND	700	ND	ND	ND	ND	Quartz-vein gossan.
54	79BT441	0.51	500	20,000	ND	- -	50	ND	NA	ND	300	ND	ND	ND	ND	Random grab samples of tourmaline-
	79BT441C	0.53	700	>20,000	ND	- -	150	ND	NA	ND	300	ND	ND	ND	ND	breccia-sulfide mineralization in
	79BT441D	0.15	40	700	1,000	10,000	50	ND	NA	ND	200	ND	ND	ND	ND	fault zone; contains chalcopyrite, pyrite, and sphalerite.

Table 6. (cont.)

Map no.	Field no.	Au	Ag	Cu	Pb	Zn	Ni	Cr	Co	W	V	Sb	Y	Bi	Zr	Remarks
55	79GL308R	0.00	ND	50	ND	ND	20	ND	NA	ND	700	ND	ND	ND	ND	Cossanized monzonite intrusive
56	79BT456	0.67	ND	70	ND	200	35	700	NA	ND	500	ND	ND	ND	ND	quartz-carbonate vein near intrusive-volcanic contact.
57	79GL318	0.67	100	20,000	ND	ND	20	ND	NA	300	150	ND	ND	ND	ND	High-grade sulfide mineralization similar to map no. 54.
58	79GL321	0.06	500	5,000	7,000	ND	20	ND	NA	ND	300	150	ND	100	ND	Gossan vein system in dike swarm.
59	79BT495	ND	7.0	100	ND	200	50	20	NA	ND	500	ND	ND	ND	ND	Gossan development in intrusive.
60	79BT515	0.01	5.0	70	ND	200	200	700	NA	ND	300	ND	ND	ND	ND	Altered mafic(?) dike.
61	79BT285	0.05	ND	15	ND	ND	5	ND	NA	ND	ND	ND	ND	ND	ND	Grab sample, rhyolite dike with quartz in prospect pit.
62	79BT285+	0.02	2.0	50	ND	200	20	ND	NA	ND	300	ND	ND	ND	ND	Quartz-carbonate-iron vein.
63	79BT181	0.01	ND	20	ND	ND	50	ND	NA	ND	300	ND	ND	ND	ND	Random grab sample, quartz vein in prospect pit.
65	79BT180	1.17	ND	50	ND	ND	20	ND	NA	ND	300	ND	ND	ND	ND	Quartz-gossan vein in dark-gray siltstone.
66	79BT178	0.00	ND	150	ND	ND	100	ND	NA	ND	300	ND	ND	ND	ND	Prospect pit vein in sandstone.
67	79BT177	0.00	ND	50	ND	ND	50	20	NA	ND	200	ND	ND	ND	ND	Quartz-vein gossan.
68	79BT122B	1.11	ND	10	ND	ND	5	ND	NA	ND	300	ND	ND	ND	ND	Mineralized quartz vein in dacite dike.
69	79BT125	0.00	5.0	7	ND	ND	100	700	NA	ND	1,000	ND	ND	ND	ND	Mafic dike.
70	79BT126	0.01	5.0	100	ND	ND	50	1,000	NA	ND	500	ND	ND	ND	ND	Altered mafic-dike gossan.
71	79BT127A	0.44	2.0	50	ND	ND	10	20	NA	ND	300	ND	ND	ND	ND	Andesite(?) dike gossan.
	79BT127B	0.14	ND	7	ND	ND	10	ND	NA	ND	300	ND	ND	ND	ND	Rhyolite-dike gossan.
	79BT127C	0.00	ND	70	ND	ND	20	ND	NA	ND	100	ND	ND	ND	ND	Quartz vein with ferricrete cement.
79	79BT95	0.00	5.0	20	ND	ND	50	ND	NA	ND	300	ND	ND	ND	ND	Ferricrete-stained vein in sandstone.
80	79BT97	0.00	ND	30	ND	ND	20	ND	NA	ND	500	ND	ND	ND	ND	Sandstone gossan.
84	79GL57	0.28	ND	15	ND	ND	20	ND	NA	ND	200	ND	ND	ND	ND	Quartz-vein chips from prospect pit.
87	79BT120	0.05	ND	15	ND	ND	30	ND	NA	ND	300	ND	ND	ND	ND	Altered rhyolite dike.
88	79BT114	0.19	2.0	100	ND	ND	10	ND	NA	ND	500	ND	ND	ND	ND	Mineralized samples from trenched
	79BT114A	0.19	ND	50	ND	ND	10	20	NA	ND	300	ND	ND	ND	ND	vein system at Independence gold
	79BT114B	0.11	ND	15	ND	ND	50	ND	NA	ND	300	ND	ND	ND	ND	mine. 114A-F are channel
	79BT114C	0.06	ND	15	ND	ND	10	ND	NA	ND	300	ND	ND	ND	ND	samples of quartz carbonate sul-
	79BT114D	0.21	ND	10	ND	ND	20	ND	NA	ND	300	ND	ND	ND	ND	fide vein along 400 ft of lode
	79BT114E	2.98	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA	NA	NA	strike length; 114E is from vein
	79BT114F	0.16	ND	7	ND	ND	20	ND	NA	ND	300	ND	ND	ND	ND	near caved portal.
89	79BT113A	0.00	ND	150	ND	ND	70	ND	NA	ND	300	ND	ND	ND	ND	
	79BT113B	0.02	ND	50	ND	ND	20	ND	NA	ND	300	ND	ND	ND	ND	

Table 6. (cont.)

Map no.	Field no.	Au	Ag	Cu	Pb	Zn	Ni	Cr	Co	W	V	Sb	Y	Bi	Zr	Remarks
90	79GL63	0.18	ND	70	ND	ND	20	ND	NA	ND	200	ND	ND	ND	ND	Quartz vein in prospect pit samples.
91	79GL62	0.35	ND	50	ND	ND	20	ND	NA	ND	150	ND	ND	ND	ND	Ferricrete-stained quartz in prospect pit.
92	79GL61	7.02	ND	70	ND	200	15	ND	NA	ND	300	ND	ND	ND	ND	Ferricrete-stained quartz in prospect pit; free gold observed in hand specimen.
93	79BT103	0.73	5.0	50	ND	ND	50	150	NA	ND	500	ND	ND	ND	ND	Prospect pit near map no. 92.
94	79BT102	0.12	5.0	30	ND	ND	10	20	NA	ND	500	ND	ND	ND	ND	Quartz vein--rhyolite dike in prospect pit.
97	79BT104+	0.23	ND	70	ND	ND	20	ND	NA	ND	50	ND	ND	ND	ND	Quartz-vein chip sample altered
98	79BT111	0.08	ND	7	ND	ND	20	ND	NA	ND	200	ND	ND	ND	ND	dike in prospect pit.
105	79BT34	0.03	1.0	100	ND	ND	10	20	NA	ND	700	ND	ND	ND	ND	Altered intermediate dike.
106	79BT29	0.03	ND	50	ND	ND	10	ND	NA	ND	100	ND	ND	ND	ND	Quartz vein in dacite dike.
107	79BT30	0.00	5.0	20	ND	ND	50	20	NA	ND	300	ND	ND	ND	ND	Quartz vein in dacite(?) dike.
109	79BT21+	0.01	ND	50	ND	ND	100	ND	NA	ND	100	ND	ND	ND	ND	Quartz-vein gossan.
110	79BT20	0.03	7.0	30	ND	ND	50	1,000	NA	ND	1,000	ND	ND	ND	ND	Altered mafic dike.
111	79BT16	0.00	5.0	10	ND	ND	200	2,000	NA	ND	500	ND	ND	ND	ND	Altered mafic dike with gossan.
114	79BT12	0.00	ND	7	ND	ND	20	ND	NA	ND	500	ND	ND	ND	ND	Rhyolite-dike rubble.
115	79BT6	0.02	ND	3	ND	ND	5	ND	NA	ND	200	ND	ND	ND	ND	Rhyolite dike.
116	79BT3	0.01	ND	10	ND	ND	5	ND	NA	ND	150	ND	ND	ND	ND	Hornfels with ferricrete staining.
119	79BT66	0.02	5.0	200	ND	ND	100	20	NA	ND	300	ND	ND	ND	ND	Gossan-quartz vein in prospect trench, associated with dike.
124	79BT64	0.01	3.0	10	ND	ND	5	20	NA	ND	500	ND	ND	ND	ND	Altered dike with gossan.
127	79BT73	0.01	5.0	30	ND	ND	30	ND	NA	ND	200	ND	ND	ND	ND	Quartz vein in sandstone.
131	78BT456	ND	1.0	77	15	52	5	50	ND	ND	300	ND	ND	ND	ND	Siderite breccia near altered dike.
132	78BT459a	ND	0.8	96	17	69	50	5,000	30	ND	300	ND	200	ND	200	Large altered mafic dike system
	78BT459b	ND	0.8	59	21	92	5	1,000	10	ND	300	ND	ND	ND	200	several hundred yards wide; in-
	78BT459c	ND	0.6	700	12	71	20	1,000	50	ND	300	ND	100	ND	ND	trudes sedimentary rocks.
146	78BT412	ND	0.6	63	14	98	50	100	30	ND	500	ND	ND	ND	ND	Altered basalt agglomerate with some gossan development.
147	78BT417	ND	0.5	26	19	90	20	ND	10	ND	150	ND	ND	ND	ND	Altered lithic sandstone.
151	79BT45	0.00	7.0	15	ND	ND	10	ND	NA	ND	200	ND	ND	ND	ND	Iron-stained shale unit.
158	79BT58	0.00	5.0	70	ND	ND	20	500	NA	ND	500	ND	ND	ND	ND	Altered mafic dike with gossan.
163	79BT199	0.01	ND	5	ND	200	20	ND	NA	ND	ND	NA	ND	ND	ND	Mineralized(?) rhyolite plug.
165	79BT205	0.01	5.0	700	ND	200	10	ND	NA	ND	300	ND	ND	ND	ND	Siderite-quartz vein in sandstone.
166	79BT194	0.01	5.0	50	ND	200	50	1,000	NA	ND	500	ND	100	ND	ND	Mafic dike with alteration.
173	78BT467	ND	0.6	222	10	107	ND	ND	20	ND	500	ND	ND	ND	500	Altered porphyritic basalt.
174	78BT462	ND	0.2	70	100	36	20	20	20	ND	200	ND	ND	ND	500	Altered border phase, syenite-monzonite.

Table 6. (cont.)

Map no.	Field no.	Au	Ag	Cu	Pb	Zn	Ni	Cr	Co	W	V	Sb	Y	Bi	Zr	Remarks
175	78BT392	ND	0.2	77	20	26	20	ND	10	ND	200	ND	ND	ND	ND	Diorite with minor quartz veins.
176	78BT391	ND	0.2	75	11	40	ND	ND	20	ND	150	ND	ND	ND	ND	Iron-stained mineralized monzonite.
177	78BT390	ND	0.8	83	24	94	20	20	20	ND	500	ND	ND	ND	ND	Breccia zone in monzonite.
178	78BT388	ND	0.4	80	19	60	20	ND	10	ND	200	ND	ND	ND	ND	Diabasic border phase.
179	78BT387	ND	0.6	68	23	55	70	1,000	50	ND	500	ND	ND	ND	ND	Iron-stained porphyroblastic hornfels.
181	77BT249	0.03	13.7	280	99	1,050	81	NA	NA	NA	NA	NA	NA	NA	NA	Iron-stained hornfelsed intrusive border phase.
184	78CL328	ND	0.5	77	10	61	20	1,000	30	ND	500	ND	ND	ND	ND	Iron-stained mafic intrusive rock near contact with country rock.
187	78BT443	ND	0.5	77	9	50	50	50	20		500	ND	ND	ND	200	Hornfels at intrusive contact.
188	78BT446	0.24	0.8	39	18	75	ND	20	20	ND	300	ND	ND	ND	ND	Cinnabar ore from prospect dump; contains some arsenopyrite.
193	79BT267A	0.00	2.0	10	ND	ND	10	ND	ND	ND	500	ND	ND	ND	ND	Manganese-stained breccia in
	79BT267B	0.01	5.0	100	ND	ND	15	ND	ND	ND	1,000	ND	ND	ND	ND	hornfels aureole; prospect pits sampled.
199	78CL300	ND	0.5	187	14	79	20	ND	20	ND	200	ND	ND	ND	200	Gossan developed in amygdaloidal basalt unit.
200	78BT376	ND	0.7	148	14	75	50	ND	30	ND	500	ND	ND	ND	200	Basalt.
201	78BT381	ND	0.2	48	11	67	ND	ND	10	ND	500	ND	ND	ND	200	Iron-stained contact zone, monzonite-basalt.
202	78BT375	ND	0.6	313	107	72	20	20	20	ND	300	ND	ND	ND	200	Gossan in basalt.
203	77BT243	0.03	12.9	240	18	68	17	NA	NA	NA	NA	NA	NA	NA	NA	Iron-stained basalt with sulfide-bearing epidote blebs.
204	78BT382a	ND	1.4	169	130	246	50	ND	10	ND	200	ND	ND	ND	500	Ferricrete gossan in hornfels breccia zone.
205	77BT242	0.01	2.23	33	122	27	20	NA	NA	NA	NA	NA	NA	NA	NA	Gossan in border phase--hornfels contact zone.
206	78BT364	ND	0.9	233	14	69	20	20	20	ND	500	ND	ND	ND	200	Porphyritic basalt with visible chalcopyrite blebs.
207	78BT366	ND	0.7	190	11	34	ND	20	ND	ND	300	ND	ND	ND	200	Gossan zone in porphyritic basalt.
212	78BT369	ND	0.4	173	9	65	50	20	ND	ND	150	ND	ND	ND	200	Hornfels breccia with manganese-iron veining.
213	77BT237	0.05	5.43	99	4	112	44	NA	NA	NA	NA	NA	NA	NA	NA	Hornfels breccia.
214	77BT238	0.02	4.10	78	8	102	47	NA	NA	NA	NA	NA	NA	NA	NA	Iron-stained hornfels.
219	77BT230	0.06	12.2	116	167	16	139	NA	NA	NA	NA	NA	NA	NA	NA	Sulfide nodules in shear zone of deformed Cretaceous(?) sedimentary rocks.

Table 6. (cont.)

[a]Analytical work by M.R. Ashwell and N.C. Veach, DGGS Minerals Laboratory. Cu, Pb, Zn, Ag, Au, and Ni in 1977 and 1978 samples (see field no. prefix) analyzed by atomic absorbtion spectrophotometry. Gold in 1979 samples also analyzed by atomic absorbtion spectrophotometry. All remaining elements in 1978 and 1979 samples analyzed by emission spectrography. Underlined samples are considered anomalous. Be, Sn, Mo, and Nb were below the limits of detection in all rock samples. NA = not analyzed. ND = not detected. For limits of detection and analytical procedure data, see appendixes 1 and 2. Silver anomalies of less than 10 ppm and vanadium anomalies (underlined) are considered questionable by the authors.

Table 7. Analyses of pan concentrates from the McGrath-Upper Innoko River area (analyses in ppm)[a]

Map no.	Field no.	Au	Ag	Cu	Pb	Zn	Ni	Cr	Co	V	Zr
2	79BT1033PC	1.90	2.0	70	ND	ND	30	20	NA	700	ND
3	79BT1031PC	0.01	2.0	50	ND	ND	20	ND	NA	500	ND
4	79BT1032PC	0.01	1.1	15	ND	ND	20	ND	NA	500	ND
5	79BT1038PC	0.02	2.0	20	ND	ND	20	150	NA	300	ND
7	79BT1030PC	0.00	1.0	20	ND	ND	20	ND	NA	500	ND
81	79BT1025PC	0.02	2.0	20	ND	ND	50	ND	NA	300	ND
83	79BT1024PC	0.01	2.0	30	ND	ND	50	ND	NA	500	ND
101	79BT1007PC	0.01	1.0	70	ND	ND	20	ND	NA	300	ND
102	79BT1006PC	0.16	2.0	50	ND	ND	20	ND	NA	500	ND
120	79BT1000PC	0.00	1.0	10	ND	ND	20	ND	NA	300	ND
125	79BT1036PC	0.02	1.0	20	ND	ND	50	ND	NA	300	ND
129	79BT1040PC	0.01	1.0	20	ND	ND	20	ND	NA	300	ND
133	79BT1011PC	0.01	1.0	10	ND	ND	30	ND	NA	200	ND
134	79BT1008PC	0.00	2.0	10	ND	ND	20	20	NA	200	ND
136	79BT1009PC	0.02	1.0	10	ND	ND	30	ND	NA	150	ND
140	79BT1018PC	0.02	2.0	15	ND	ND	50	ND	NA	300	ND
141	79BT1017PC	0.01	2.0	20	ND	ND	20	ND	NA	200	ND
142	79BT1016PC	0.02	2.0	50	ND	ND	20	ND	NA	300	ND
143	79BT1015PC	0.03	2.0	10	ND	ND	50	ND	NA	200	ND
144	79BT1014PC	0.02	5.0	20	ND	ND	20	ND	NA	300	ND
145	79BT1013PC	0.01	1.0	7	ND	ND	30	ND	NA	300	ND
162	79BT1012PC	0.00	2.0	15	ND	ND	50	ND	NA	200	ND
180	78BT421	ND	0.4	67	ND	74	50	100	20	500	200
182	78BT422	ND	0.6	76	21	153	10	100	20	500	200
191	79BT1052	0.01	2.0	15	27	ND	20	ND	ND	300	ND
192	79BT1048	0.01	23.0	70	5,000	ND	50	ND	ND	500	ND
195	79BT283	0.00	2.0	20	ND	ND	ND	30	ND	300	ND
197	79BT284	0.02	3.0	50	ND	ND	20	ND	ND	300	ND
198	79BT1054	0.01	2.0	7	ND	ND	10	ND	ND	300	ND
210	77BT235b	520.0	67.3	42	109	99	17	NA	NA	NA	NA

[a]Analytical work by N.C. Veach and M.R. Ashwell, DGGS Minerals Laboratory. Cu, Pb, Zn, Ag, Ni, and Au in 1977 and 1978 samples (see field-number prefix) analyzed by atomic absorbtion spectrophotometry. Silver and gold in 1979 samples also analyzed by atomic-absorbtion spectrophotometry. All remaining elements in 1978 and 1979 samples analyzed by emission spectrography. Be, Sn, Mo, Nb, Bi, Y, Sb, and W were below the limits of detection in all pan concentrates. NA = not analyzed. ND = below the limits of detection (see appendixes 1 and 2). Underlined values are considered anomalous. Ag anomalies of less than 10 ppm are considered questionable by the authors.

Table 8. Mineralogical identification of two heavy-mineral concentrates from mining operations in the Ophir mining precinct[a]

1. Spruce Creek concentrates (78BT501)
   - Major minerals ($\geq$10%)
     - Magnesiochromite-chromite (solid solution ([$MgCr_2O_4$] [$FeCr_2O_4$])
     - Garnet
     - Ilmenite
   - Minor minerals ($\leq$10%)
     - Gold
     - Pyrite
     - Scheelite
     - Zircon
     - Magnetite

2. Yankee Creek concentrates (78BT502)
   - Major minerals ($\geq$10%)
     - Ilmenite
     - Magnesiochromite-chromite (solid solution ([$MgCr_2O_4$] [$FeCr_2O_4$])
     - Pyrite
     - Zircon
   - Minor minerals ($\leq$10%)
     - Magnetite
     - Garnet
     - Scheelite
     - Barite

[a]X-ray diffraction analysis by N.C. Veach, DGGS Minerals Laboratory.

Table 9. Ophir precinct gold production by creek (includes Candle Creek)[a]

Creek	Last recorded year	Gold (oz)	Silver (oz)
Anvil	1950	3,394	12
Democrat	1924	947	21
Dodge	1917	408	40
Ester	1964	1,110	210
Ganes	1969	88,111	15,220
Gold Run	1948	1,227	245
Little	1966	37,681	6,120
Madison	1941	2,119	286
Spaulding	1941	7,925	1,541
Ophir	1961	66,489	7,004
Victor Gulch	1958	2,690	332
Yankee	1968	57,084	6,361
Mackie	1938	943	54
Fox Gulch	1922	167	17
Candle Creek	1950	129,500	12,210

[a]Unpublished mint returns only; all figures are conservative. Does not include gold production that has taken place almost continuously through 1980 on Spruce, Anvil, Ganes, and Little Creeks.

Table 10. Uranium-thorium analytical results from plutonic rocks in the McGrath-upper Innoko River area.[a]

Map no. (pl. 2)	Field no.	Rock type	Uranium (ppm)	Thorium (ppm)	Th/U
1	78-BT-379	Biotite-pyroxene monzonite	16.4	15	0.91
2	79-GL-154	Quartz monzonite	3.7	6	1.62
3	79BT-TAT. PLUTON	Biotite monzonite	7.6	20	2.63
4	79-GL-150	Quartz monzonite	8.9	24	2.70
5	79-BT-409	Monzonite	8.5	21	2.47
6	79-BT-432	Biotite-pyroxene monzonite	11.8	19	1.61
7	79-BT-442	Pyroxene monzo-diorite	7.1	15	2.11

[a]Analyses (courtesy of Dr. R.B. Forbes, Alaska Geological & Geophysical Surveys consultants) by Atomic Energy of Canada Limited. Uranium assays were obtained by instrumental neutron-activation analysis, by using the delayed neutron counting technique. The assay analysis procedure for uranium uses a 60/10/60 sec irradiation history with a thermal neutron flux of $5 \times 10^{11} n/cm^2/sec$. The sensitivity is 0.2 µg uranium. For a nominal 1-g sample the measurement precision is ± 10% at 1 ppm U, ± 5% at 10 ppm U and ± 1% or better at 100 ppm U. All irradiations are performed in a Slowpoke-2 nuclear reactor.

Instrumental neutron activation analysis (INAA) for thorium also uses a Slowpoke-2 reactor. The typical irradiation history is 4 hr/7d/15 min with a thermal neutron flux of $2.8 \times 10^{11} n/cm^2/sec$. Measurements are carried out on a 40-cc Li/Ge detector which has an efficiency of 11% and a resolution of 2.8 KeV FWHM. A Nuclear Data 6600 multichannel analyzer is used for data acquisition and handling. Thorium-232 is determined from the PA-233 (t1/2 27d) daughter. The sensitivity is approximately 1 ppm Th in geological samples. For a nominal 0.5-g sample the measurement precision is conservatively estimated as the sum of a 5% error for sample weighing, counting geometry, flux variations etc., plus a measured error in the calibration samples (approximately 5%) plus a 1 standard-deviation counting statistical error.

Geochemical XRF thorium analyses are run on a Siemens XRF unit with a molybdenum target using the dry-powder technique. Pellets are pressed at 15 tons. The sensitivity is quoted at 1 ppm Th with a measurement precision of ± 100% at 1 ppm Th, ± 12% at 10 ppm Th and ± 5-10% at 300 ppm Th.

APPENDIX 1

Sampling Procedure and Analytical Techniques for Geochemical Samples

Rock, pan-concentrate, and stream-sediment samples were collected by the authors and V.F. Ferrell, K.S. Emmel, and N.D. Coursey during the 1977-79 field seasons. Stream-sediment samples of the finest fractions available below the waterline were collected generally at creek mouths, and occasionally along creek systems at 1/2-mile intervals during geologic mapping traverses. An effort was made to 1) exclude highly organic material and 2) obtain a fine fraction derived from the weathering of nearby bedrock sources rather than from windblown loess. Pan concentrates were collected from selected locations throughout the study area by using a 'standard' gold pan (with 16-in.-diameter top) and a 4 mesh sieve. Gravel and sand were shoveled onto the sieve and the $\leq$ 4 mesh fraction collected in the pan. This material was subsequently panned and the heavy mineral fraction retained. Both pan-concentrate and stream-sediment samples were dried in the field.

Chip and grab samples were collected from mineralized zones, prospects, and old mines to obtain an indication of the elemental content of mineral occurrences found within the area. Except for samples collected at the Independence Mine (map no. 88, pl. 2 and fig. 2) and the Spruce Creek-Little Creek rhyolite prospect (map no. 41, pl. 2; fig. 3), no channel samples were collected; thus accurate estimates of the grade of mineral deposits in the study area cannot be made, and analytical results presented in table 6 should be viewed only as indicators of mineralization in the study area.

Elemental analyses were performed at the DGGS Mineral Analysis Laboratory by M.R. Ashwell, N.C. Veach, and Coursey. Atomic-absorbtion spectrophotometric analysis was carried out by taking a 10-g sample and digesting it in an appropriate amount of aqua regia. The digestate was filtered and diluted to 100 mm final volume containing 70 percent acid. For 1977 and 1978 samples (see field no. prefix in tables 6-8), the elements Cu, Pb, Zn, Ag, Ni, and Sb were aspirated directly into the air-acetylene flame; gold in all samples (except 1979 stream sediments) was determined following a DIBK-Aliquat 336 solvent-solvent extraction. All analyses were performed on a Perkin-Elmer 603 Atomic Absorbtion Spectrophotometer.

The emission spectrographic analyses were performed using a Jarrell-Ash 1.5 m Wadsworth type grating spectrograph, equipped with a Jarrell-Ash model JA 43-650 Spectro-Varisource power supply control. Films were developed by using a Jarrell-Ash model JA 34-300 photo processor and concentrations were determined by using a Baird Atomic model RC-3 microphotometer.

In this procedure, 5 mg of -100 mesh rock powder are mixed with 10 mg of graphite powder and packed into a graphite electrode. The electrode is excited by a direct current arc increased by steps to a maximum of 10 amps. The spectrum is recorded on Kodak Spectrum Analysis No. 1 film with an exposure time of 180 seconds. The film is processed with Kodak D-19 developer at 20°C for 3 minutes and fixed with Kodak rapid fixer for 3 minutes and air dried.

Elemental concentrations are determined by the line comparison method. Generally, the most sensitive elemental line is chosen for comparison. The concentration is determined by comparing the intensity of the line of the element sought, to lines of known concentration on a standardized film. Standard concentrations are on a 1, 2, and 5 step scale, i.e., concentrations would read in ppm: 1, 2, 5, 10, 20, 50, and 100, etc. Unknown concentrations are read directly in ppm or percent.

APPENDIX 2

Lower detection limits for elements analyzed (in ppm)

Au (AAS) 0.01	Co (E.spec) 10
Ag (AAS) 0.1	Sn (E.spec) 20
Ag (E.spec) 1	W (E.spec) 20
Cu (AAS) 1	V (E.spec) 20
Cu (E.spec) 5	Sb (E.spec) 100
Pb (AAS) 1	Sb (AAS) 1
Pb (E.spec) 20	Y (E.spec) 100
Zn (AAS) 1	Bi (E.spec) 20
Zn (E.spec) 200	Zr (E.spec) 200
Ni (AAS) 1	Be (E.spec) 1
Ni (E.spec) 2	Mo (E.spec) 10
Cr (E.spec) 20	Nb (E.spec) 10

APPENDIX 3

Average abundances of selected elements in the earth's crust in three common rocks (in ppm).
From Krauskopf (1979, p. 544-45).

	Granite	Basalt	Shale	Crust
Au	0.002	0.004	0.003	0.003
Ag	0.04	0.1	0.1	0.07
Cu	12	100	50	50
Pb	20	3.5	20	12.5
Zn	50	100	90	70
Ni	0.8	150	80	75
Cr	20	200	100	100
Co	3	48	20	22
Sn	3	2	6	2.5
W	1.5	0.8	1.8	1.2
V	50	250	130	110
Sb	0.2	0.2	1.5	0.2
Y	40	30	35	35
Bi	0.2	0.1	0.2	0.15
Zr	180	140	180	165
Be	5	0.5	3	3
Mo	1.5	1	2	1.5
Nb	20	20	15	20