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T.K. Bundtzen, B.C. Cox, and N.C. Veach

Alaska Division of
Geological and Geophysical Surveys

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794 University Avenue, Suite 200
Fairbanks, Alaska 99709-3645

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T.K. Bundtzen[1], B.C. Cox[2], N.C. Veach[1]

[1]Alaska Division of Geological and Geophysical Surveys, 794 University Avenue, Basement, Fairbanks, Alaska 99709.
[2]NERCO Minerals Company, 4821 Northeast Thurston Way, Suite B, Vancouver, Washington 98662.

Abstract

Placer gold in the Iditarod and Innoko mining camps of western Alaska is derived from a suite of comagmatic, Late Cretaceous to Early Tertiary, alkali-calcic, meta-aluminous, volcanic-plutonic complexes and peraluminous rhyolite sills that intrude Mesozoic flysch. Heavy-mineral concentrates from 42 mining operations and streams draining known mineralized areas in the igneous complexes contain placer gold and a variety of ore minerals derived from epithermal to hypothermal conditions of formation. The minerals include cassiterite, ilmenorutile, samarskite, cinnabar, scheelite, chromite, stibnite, silver sulfosalts, monazite, and zircon. Results of the study show that 1) cinnabar, stibnite, and quartz formed with the bulk of the placer gold in an epithermal lode environment, 2) chromite appears to have originated in mafic phases of monzonite plutons and alkalic basalts, and 3) niobium-tin-tungsten-uranium-silver values may have been derived from stockwork accumulations in cupolas of monzonite plutons.

Introduction

Since the late 1970s, the Alaska Division of Geological and Geophysical Surveys (DGGS) has conducted 1:63,360 scale geologic mapping and mineral resource investigations in the Innoko and Iditarod districts of western Alaska. Work since 1984 has been conducted in cooperation with the U.S. Geological Survey. Geologic mapping and topical mineral studies have been released in DGGS professional reports (1, 2, 3, 4), and in geology and mineral conferences (5, 6, 7). Both mining districts have had a substantial history of placer gold production which has totaled 2.118 million ounces since 1907 (table 1).

The geologic mapping has shown that Late Cretaceous-to-Early Tertiary (LK-ET) igneous complexes seem to be the source of nearly all of the placer gold and other exploited heavy minerals including cinnabar, stibnite, scheelite, and byproduct silver. Hence, an effort was made to collect heavy mineral concentrates from present and past producing placer mines and from streams draining LK-ET igneous complexes. Prior to this work the only other published mineral concentrate investigation (8) reported radioactive minerals in selected portions of the study area. The purpose of this study is several fold. First, we seek to establish a methodology for systematic heavy mineral identification and geochemical analyses. Second, a study of ore and gangue mineralogy can result in a better understanding in overall metallogenic processes of the study area. Finally, integration of the heavy mineral placer provenance studies with the bedrock and surficial geology can provide a valuable prospecting tool for both lodes and placers. This report summarizes the results of the heavy minerals sample collection effort.

Table 1. Placer gold and silver production in Innoko and Iditarod districts, Alaska.*

Mining district and stream drainage	Known productive years	Gold (troy oz)	Silver (troy oz)	References	Remarks
Innoko/Tolstoi					
Graham	1917?-1963	65	6	(9)	- - -
Colorado	1917-1966; 1978-1986	51,600	4,644	(9, 10)	Minimum estimate used for 1978-86 production.
Bear	1917-1961; 1970-1986	10,412	1,150	(9)	No production since 1961 included.
Cripple	1917-1955; 1978-1986	38,542	401	(9)	No recent production included.
Esperanto	1917(?)-1962	4,429	699	(9)	Production through 1962.
Madison	1919(?)-1947; 1982-1985	3,103	338	(9, 11)	Production known through 1984.
Boob	1916-1918; 1982-1986	3,170	320	(9)	Conservative.
Subtotal		111,321	7,558		- - -
Innoko/Ophir					
Gold Run	1910-1948	1,277	245	(9)	- - -
Beaver	1910-1950	1,640	163	(9)	- - -
Anvil	1910-1950; 1970s-1986	3,394	12	(1)	No recent production included.
Democrat	1910-1924	947	21	(1)	- - -
Dodge	1917(?)-1962	408	40	(1)	- - -
Ester	1910-1964; 1980-1986	1,110	210	(9)	Recent production unknown.
Ganes	1907-1986	103,000	15,420	(9, 12)	Believed to be conservative.
Spruce	1909-1950; 1955-1986	35,400	4,600	(9, 13)	Conservative.
Little	1908-1986	47,600	8,092	(9)	Minimum estimate for recent production used.
Ophir	1908-1961; 1978-1985	66,489	7,004	(9)	Recent production (since 1961) unknown.
Victor Gulch	1909-1958	2,690	332	(9)	- - -
Yankee	1909-1968; 1981-1986	62,500	12,650	(9, 14)	Conservative
Spaulding	1909-1941	7,925	1,541	(1)	- - -
Undistributed production	- - -	6,986	1,089	(9)	Locations poorly understood.
Subtotal		341,366	51,419		- - -
Innoko/Candle					
Candle	1914-1929; 1949-1952	129,500	12,210	(1)	- - -
Carl	1926-1929	135	14	(9)	- - -
Alder	1929-1935; 1981-1984	110	10	(9, 15)	- - -
Subtotal		129,745	12,234		- - -

Iditarod/Moore					
Moore (includes Nevada Gulch)	1910-1966; 1980-1986	54,250	12,600	(9, 16)	Probably conservative.
Fourth of July	1910-1920; 1982-1983	45	5	(9, 17)	Only most recent production known.
Subtotal		54,295	12,605		- - -
Iditarod/George					
Granite Pup	1920; 1979-1986	1,450	275	(9, 18)	- - -
Julian	1911-1939; 1947-1959; 1974-1986	9,098	1,546	(9, 19)	Very conservative; only uses production from 19 years.
Michigan	1911; 1980-1985	100	9	(20)	Only most recent production known.
Spruce	1911; 1920, 1979-1984	274	NA	(18)	Only most recent production known.
Subtotal		10,922	1,830		- - -
Iditarod/Flat					
Boulder Creek	1917	18	4	(9)	- - -
Black	1910-1981	5,800	700	(9, 21)	Most production included in Otter Creek.
Malemute Pup	1912-1952	1,907	241	(9)	- - -
Granite	1910-1956; 1980-1985	4,750	636	(9)	- - -
Otter	1908-1986	235,721	30,628	(9, 22)	Most production prior to 1968 includes Black Creek.
Slate	1915-1951	3,483	592	(9)	Last mining recorded 1951.
Flat	1910-1966; 1975-1985	477,039	51,875	(9, 21, 23)	Includes Mohawk, Upgrade, and other head-ward pups.
Prince	1913-1986	33,164	3,979	(9, 24)	Accurate mine records provided by current operator.
Happy	1910-1984	127,486	17,210	(21, 23)	May have included production from Chicken and Willow Creeks.
Willow Bench	1915?-1967; 1984-1986	41,948	5,033	(9, 23)	Probably conservative; incomplete records.
Chicken	1912-1985	24,800	3,174	(23, 25)	Probably conservative. Production records from 1940 - present are absent.
Glen Gulch	1912-1958	10,421	1,231	(9)	Last record of production 1958.
Idaho Bench	1910-1965; 1984-1985	330	15	(9)	Only recent production.
Undistributed Iditarod production	1910-1914	482,382	72,278	(9, 21)	Estimates from entire Iditarod/Flat district prior to systematic record keeping
Undistributed production	- - -	1,645	42	(9)	- - -
Subtotal		1,450,894	187,638		- - -

Iditarod/Donlin					
Donlin	1911-1956	4,170	119	(9, 26)	Production records through 1931; include Quartz, Lewis, and Snow Gulch production.
Quartz Gulch	1910-1917; 1986	1,968	14	(9)	Only 3 years of production; conservative.
Omega Gulch	1911-1939	6,089	10	(9)	Only 3 years of production; conservative.
Snow Gulch	1911-1956; 1981-1985	7,363	520	(9)	- - -
Subtotal		19,590	663		- - -
Total (Innoko)		582,432	71,211		- - -
Total (Iditarod)		1,535,701	202,736		- - -
GRAND TOTAL		2,118,133	273,947		- - -

* This compilation is based on systematic examination of all available published reference material, unpublished U.S. Mint return data and interviews with recent/contemporary mine operators. The data for U.S. Mint returns generally span the period 1914-1972 and hence do not show complete production records for the 1907-1912 'discovery era' of the Innoko/Ophir, Iditarod/Moore, and Iditarod/Donlin districts. Importantly no mint data are available after 1972, when gold was decontrolled by federal legislation. Some 20 to 27 mine operators have produced gold, more-or-less continuously, since the late 1970s to the present. We have added production to U.S. Mint and published data for these streams only when accurate estimates have been provided by mining companies. Hence all stream and district totals for bullion production must be regarded as conservative. 'Undistributed production' are U.S. Mint return information from the Innoko and Iditarod district that cannot be assigned to known mine areas. They include Mackie, Kline, Birch, Graves, Helana, Fox gulch, Lynx, and Graham Creeks in the Innoko district and Alpha and Trail Pups in the Iditarod district. None appear in the Dictionary of Alaska Place Names (27) and presumably are local pups or streams whose terminology is not currently used.

Geography

The Innoko and Iditarod mining districts cover about 20,000 km^2 north and west of the Kuskokwim River in western Alaska (fig. 1). Principal drainage systems are the Innoko, Dishna, and Iditarod Rivers, which flow into the Yukon River, and Donlin, George, and Takotna Rivers, which flow into the Kuskokwim River. The historic placer mining areas have been subdivided on the basis of local geographic and geologic divisions that generally conform to nomenclature utilized in past studies including those of Mertie and Harrington (28), Mertie (29), and Cobb (30). Because of regional geologic/ geographic variations, three sub-units of the Innoko districts (Tolstoi, Ophir, and Candle) and four sub-units of Iditarod (Moore, Flat, George River, and Donlin) are used in this study.

Both the Iditarod and Innoko districts lie within the Kuskokwim Mountains, a maturely dissected upland of accordant rounded ridges averaging 600 m in elevation, with broad sediment-filled lowlands averaging 100 m in height. The bulk of the two mining areas was not glaciated during Quaternary time and the maturely dissected ridgelines are similar to those of other major interior Alaska placer districts including Fairbanks, Circle, Fortymile, Manley-Tofty, and Poorman areas. Notable uplands including the Beaver and Cripple Mountains and Chicken, Twin, Cloudy, and Camelback Mountain are rugged igneous-cored massifs that rise 250 to 800 m higher than surrounding hills. Several of the igneous complexes have experienced Pleistocene glaciation which in turn has modified placer deposits in their respective stream drainages. The specific formation of heavy mineral placers in the region has been influenced by several major factors that include 1) the geomorphic evolution of streams during Late Tertiary-Quaternary time in a periglacial environment, 2) concentration, dispersion, and stream piracy as a result of Pleistocene glacial cycles, and 3) influence of uplift rates caused by structural tilting along high angle faults. A more detailed analysis of these factors is summarized in another paper (31).

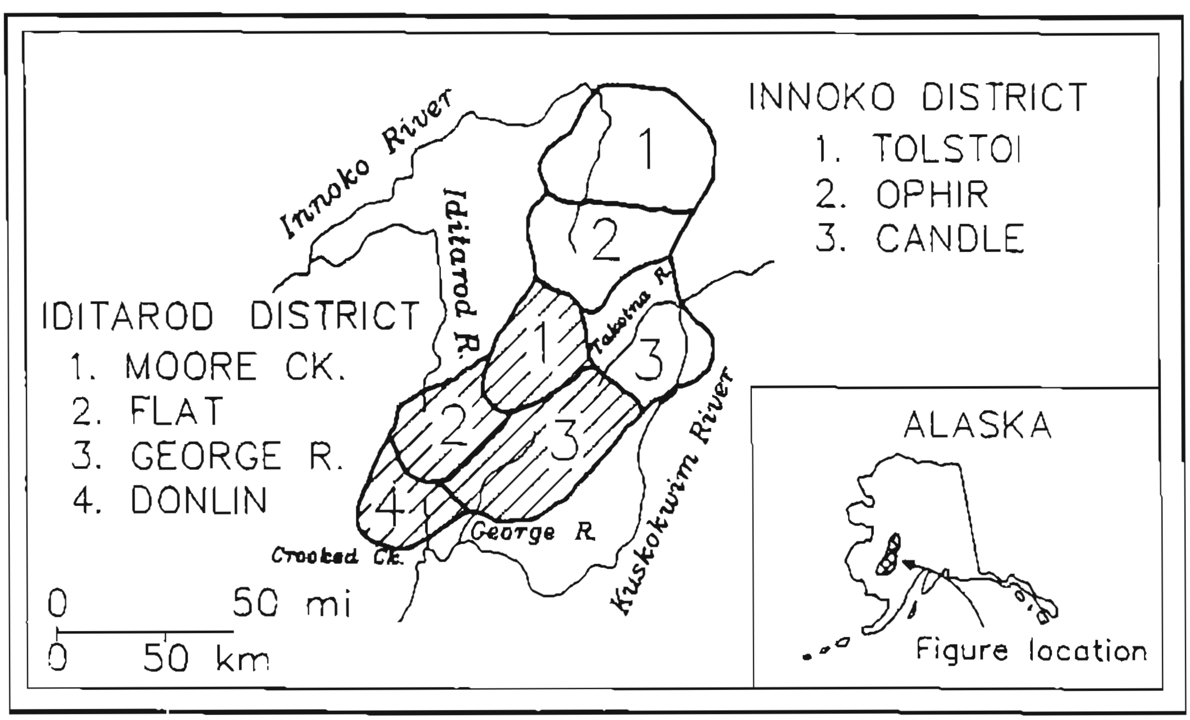

Figure 1. ocation map showing Innoko and Iditarod districts, Alaska.

Bedrock Geologic Summary

The oldest rock types crop out along the western margin of the study area and consist of chert, limestone, and clastic rocks ranging in age from Mississippian to Jurassic (fig. 2). Structurally juxtaposed against these rocks are thin slices of ultramafic/mafic cumulates of probable Jurassic age.

Blanketing these older rocks is a composite Mesozoic flysch unit known as the Kuskokwim Group (26). This flysch basin extends for over 350 km in a northeast-southwest basin and is the major lithologic unit in western Alaska. Most of LK-ET plutonic and volcanic magmas intrude these rocks.

Intruding and overlying all older rocks are nine LK-ET volcanic-plutonic complexes and peraluminous basalt-rhyolite dike swarms of Late Cretaceous-Early Tertiary age. The whole rock geochemistry emplacement history and metallogeny briefly summarized (7, 32) indicate that original volcanic fields are partly intruded and assimilated by younger plutons. On the average, the volcanic-plutonic complexes plot in the meta-aluminous alkali-calcic geochemical field.

Although the entire suite was apparently emplaced between 58 and 75 m.y. ago, preliminary K-Ar age dating and field relationships (in (7)) show that the crystallization sequence is: alkaline mafic volcanics (A = 74.7 m.y.); meta-aluminous quartz alkalic to alkali-calcic to calc alkaline monzonitic plutons (A = 68.7 m.y.); peraluminous rhyolite (A = 63.5 m.y.). The sequence of crystallization events is crudely similar to that proposed by Swan and Keith (33) for LK-ET igneous rocks in the western USA. The first two pulses are probably mantle-derived magmas showing some crustal contamination; the last peraluminous series is probably the result of anatectic melting of the crustal section (7).

Lode Mineralization

The significance of the LK-ET igneous suite is that it constitutes the source of both lode and placer mineral deposits throughout the study region, with the single exception of Boob Creek of the Innoko/Tolstoi camp.

Two monzonitic intrusions in the Iditarod-Flat districts are the source of rich residual and semi-residual placer deposits. The plutons have monzonitic cores and gabbro-rich rims and are, in part, flanked or capped by older basaltic and andesitic rocks. Large north-trending shear zones seem to be the gold sources in both plutons. The Golden Horn gold-tungsten deposit is a 30 m wide, 3 km long shear zone containing free gold, scheelite, lead-antimony sulfosalts, cinnabar, and base metals. Several thousand ounces of gold were won from mining high grade ores at Golden Horn. Similar mineralized shear zones in monzonite exist at Moore Creek and Vinasale Mountain (34), at Candle (3), and in the Cripple Mountains (29).

Dike swarms are also associated with important mineral lodes of the region. Placer gold deposits in the Innoko/Ophir, Iditarod/George, and Iditarod/Donlin districts are concentrated along slopes and streams leading from swarms of predominantly rhyolitic and fewer basaltic dikes. In the Innoko/Ophir district the swarm is controlled by the 80 km long Ganes Creek fault (1, 2). Similar fault controls may exist in other districts. The Independence gold deposit is the only lode developed commercially in the Ophir sub-unit and consists of gold-bearing quartz carbonate

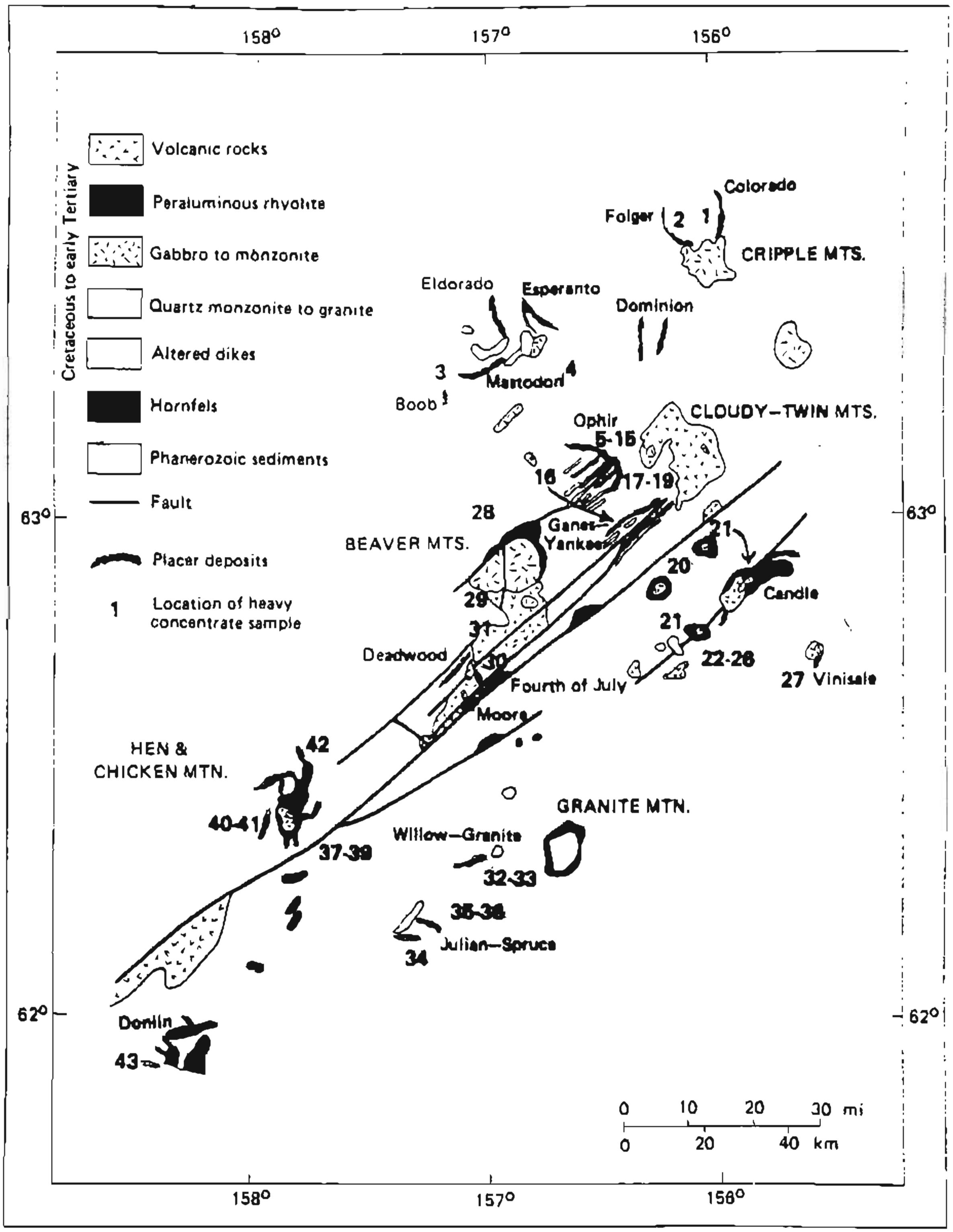

Figure 2 `implified geologic map showing location of placer deposits and heavy minera concentrate sample localities, keyed to table 2.

ores in rhyolite. Nearby mafic dikes contain anomalous chromium and nickel.

Placer Deposits

Production

The Innoko and Iditarod mining districts have been responsible for the production of at least 2.118 million ounces of gold and significant byproduct silver, tungsten, mercury, and antimony (table 1).

Details of the mining history have been described in several reports (25, 28, 29, 35, 36) and will only be briefly summarized here. Gold was discovered initially in the Innoko/ Ophir district in 1906; prospectors later found gold in Iditarod/Flat (1907), Iditarod/Donlin (1909), Iditarod/Moore (1910), Innoko/Candle (1913), and finally the Innoko/ Tolstoi camp (1916).

Typical of placer districts throughout Alaska, gold was first worked by hand methods; scraper plants and floating dredges were introduced later (by 1920), and bulldozer-dragline sluicing operations commenced in the 1930s. This last phase has continued to be the principal extraction method. The last floating bucketline dredge units ceased operations in the Innoko and Iditarod districts in 1965 and 1968 respectively. Today some 27 mechanized placer operations are extracting gold in the study area.

Gold Fineness Studies

Past U.S. Geological Survey fineness records (Smith, (37)), 'true fineness' summarized from U.S. Mint records (Metz and Hawkins, (38)), and 20 analyses conducted during DGGS investigations are summarized in table 2. Fineness ranges from 593 to 927 throughout both districts; the Smith (37) data averages 864; those of Metz and Hawkins (38) average 891; and our own results average 853.

The Metz and Hawkins (38) summary reports only true fineness, which is the ratio ($\frac{Au}{Au + Ag}$ x 1000), and does not take into account other metallic impurities. This may explain why their average fineness values are 27-38 points higher than the other data sets. Our average of 853 is probably lowered by two exceptionally low fineness samples from Julian Creek and Glenn Gulch (Iditarod district) which incorporate significantly high impurity factors. Hence the 864 average reported by Smith (37) is probably the most accurate overall average estimate of bullion purity for the region. Additional reports provided by selected mines in the Iditarod and Innoko mining districts shows that placer bullion in the two mining districts yield 81 percent gold, 15 percent silver, and 4 percent impurities. Obviously these results indicate significant shrinkage factors are encountered in the bullion refining process.

Methodology of Heavy Mineral Concentrate Analysis

During the course of geologic investigations, the first author collected mine concentrates and pan concentrates from 42 sites throughout the study area. Most mine concentrates were derived from sluice-box runs of from 10 to 20 days, and sample weight averaged 5 kg. Panned concentrates from other sites were collected by panning samples of 0.1 m^3 generally from on or near bedrock surfaces of both mined and unmined stream gravels.

Table 2. Trace element and gold fineness data for placer deposits, Innoko and Iditarod district, Alaska.[1]

Mining district and stream drainage	Sample wt. in mg (DGGS)	Gold fineness (DGGS)	Silver fineness (DGGS)	Impurities (DGGS)	Gold fineness range from Smith (37) (N)[2]	Average fineness from Smith (37)	Fineness from Metz and Hawkins (38)	Remarks
[illegible]/Tolstoi								
Colorado	1143.20	909.6	82.8	2.57	NA[3]	NA	884	+10 mesh nuggets
Colorado	270.56	900.2	91.8	8.15	NA	NA	- -	-8 to +14 mesh
Cripple	NA	NA	NA	NA	899-917 (5)	908	906	- - -
Bear	NA	NA	NA	NA	NA	NA	901	- - -
Esperanto	NA	NA	NA	NA	869-878 (N)	869	864	- - -
Madison	NA	NA	NA	NA	NA	NA	881	- - -
Boob	606.00	902.0	86.0	12.0	NA	NA	909	Past PGM production ~ 1% total gold by vol.
Innoko/Ophir								
Beaver	NA	NA	NA	NA	NA	NA	910	- - -
Dodge	NA	NA	NA	NA	NA	NA	911	- - -
Ester	NA	NA	NA	NA	NA	NA	841	- - -
Ganes	NA	NA	NA	NA	817-874 (6)	846	853	- - -
Spruce	334.25	870.7	100.3	29.0	879 (1)	879	873	From 1978 mine sample on bench
Little	NA	NA	NA	NA	825-837 (9)	830	860	- - -
Ophir	NA	NA	NA	NA	883-911 (9)	898	905	- - -
Victor Gulch	NA	NA	NA	NA	880-881 (2)	881	890	- - -
Yankee	950.10	849.6	129.5	20.9	866-886 (6)	882	900	From 1968 mine concentrate near camp
Spaulding	NA	NA	NA	NA	857 (1)	857	837	- - -
Innoko/Candle								
Candle	437.00	902.0	88.0	10.0	894-917(15)	914	902	Contains 5.40 ppm PGM
Alder	3000.00	930.0	56.0	14.0	NA	NA	NA	Contains 2.65 ppm PGM
Iditarod/Moore								
Moore	NA	NA	NA	NA	746-769(19)	758	883	- - -
Fourth of July	1160.84	853.0	146.3	0.7	NA	NA	NA	From 1982-83 mine concentrate
	650.00	899.0	61.0	39.0	NA	NA	NA	- - -
Iditarod/George								
Granite Pup	86.78	871.0	121.0	8.0	NA	NA	NA	From 1984 mine concentrate
Julian	160.44	840.0	152.0	9.0	835 (1)	835	857	From 1984 mine operation
	115.70	657.0	119.0	224.0				

Iditarod/Flat

Black	3021.00	819.0	180.0	1.0	NA	NA	925	From 1981 mine concentrate; contains 1.4 PGM
Malemute/Granite	NA	NA	NA	NA	854(14)	854	888	- - -
Otter	NA	NA	NA	NA	822-891(91)	847	885	Smith (37) values probably include Black Creek and Glen Gulch
Slat[illegible]	NA	NA	NA	NA	NA	NA	855	- - -
[illegible]	NA	NA	NA	NA	864(23)	864	902	- - -
Prince	160.39	866.0	131.0	3.0	NA	NA	881	From bench level lower Prince Creek
	117.07	886.0	112.0	2.0	NA	NA	NA	From bench level upper Prince Creek
	121.00	838.0	161.0	1.0	NA	NA	NA	From modern stream placer
Happy	5000.00	884.3	114.0	1.7	862 (7)	862	944	From 1981 mine concentrate
Willow Bench	NA	NA	NA	NA	874(23)	874	898	- - -
Chicken	NA	NA	NA	NA	850-870(14)	861	863	- - -
Glen Gulch	1458.33	593.0	297.4	109.6	NA	NA	894	DGGS sample contained quartz
Idaho Bench	21.04	861.0	132.0	7.0	NA	NA	NA	From 1984 mine concentrate

Iditarod/Donlin

Donlin	NA	NA	NA	NA	905 (5)	912	972	- - -
Quartz Gulch	NA	NA	NA	NA	NA	NA	927	- - -
Snow Gulch	1150.00	927.0	70.0	3.0	NA	NA	919	From 1984 mine concentrate

[1]This table summarizes gold fineness results from 36 gold producing stream drainages in three subdivisions of the Innoko district and four subdivisions of the Iditarod district (see figure 2 for general locations). Gold producing creeks that lack fineness information include Anvil, Democrat, and Carl Creeks (Innoko district) and Michigan, and Spruce Creeks (Iditarod district). The 20 DGGS fineness values were determined by Don Stein and N.C. Veach using fire assay methods. Those reported by Smith (37) and Metz and Hawkins (38) are presumable derived from historical mining company and U.S. mint records. Metz and Hawkins (38) report only 'true fineness' ($\frac{Au}{Au + Ag}$ x 1000) and do not account for impurities or shrinkage factors.

[2]N = Number of mine assay records.
[3]NA = Not available.

In the laboratory, the 42 concentrates were first sieved using techniques described in detail (39). Standard sieve sizes used were two phi (Ø), 2.5Ø, 2.75Ø, 3.5Ø, and 3.75Ø. Raw weight, cumulative weight, cumulative percent and individual percent were calculated for each size fraction.

The 3.5Ø and 3.75Ø fractions were separated according to specific gravity using reagent grade bromoform (sp.g. = 2.89) as the separation medium. Sample and bromoform were combined in 50 ml plastic centrifuge tubes using 10 ml bromoform to each 1 gm of sample, limiting sample size to 3 gm. Each prepared sample was then centrifuged for 20 minutes at 1,800 rpm. Subsequently, each centrifuge tube containing the concentrated heavies was submersed in an ice-saltwater solution until frozen. The unfrozen bromoform and suspended 'light' minerals were poured through a funnel using a No. 1 filter paper. The frozen bromoform containing the heavy fraction was melted in hot water and reclaimed. This method of separating 'heavy' minerals was found to be much less time consuming than traditional funnel techniques; separation time averaged approximately 40 minutes per 3 gm sample.

The heavy fractions from each pan concentrate were further separated according to magnetic susceptibilities. Magnetite was removed with a plunger type hand magnet. Final sample separates were obtained using a Frantz model L-1 magnetic separator. Amperage settings were .05 amp, .2 amp, .5 amp, .7 amp, 1.2 amp, and 1.7 amp at a forward tilt angle of 15° and a side tilt of 25°. The purpose of this step was to decrease mineral variability of each powder slide in order to improve X-ray trace quality of the diffraction traces and to simplify mineral identification.

This methodology applied to the original 42 pan concentrates produced 204 samples that were analyzed using the DGGS Rigaku X-ray diffractometer system. Polished grain mounts and macroscopic observations also aided in determining mineralogy. Cox processed and analyzed 23 of the 42 samples; Veach and Bundtzen ran the remaining sample suite.

The minerals identified by visual and/or X-ray analysis are listed in table 3. The laboratory work confirmed the presence of 41 heavy mineral species including 23 ore minerals containing iron, titanium, mercury, silver, niobium-tantalum, copper, lead, tin, tungsten, uranium, thorium, antimony, molybdenum, and rare earth elements. Due to the presence of more than one mineral on the X-ray slides, some identifications are tentative. Where questions arose or exotic minerals were encountered, supportive opinions were obtained from P.D. Rao of the University of Alaska Mineral Industry Research Laboratory in Fairbanks.

The mineralogical identification summarized in table 3 were cross-checked with geochemical analyses of 33 of the 42 sample splits (table 4). The 21 element analyses generally cover those predicted to occur in the mineralogical suite. However, only limited analyses exist for uranium, tin, tungsten, thorium, and yttrium. Hence geochemical analyses cannot be used in all cases to confirm mineralogical identification by the X-ray diffraction method.

Heavy Mineral Provenance

Besides the heavy mineral concentrate study, the authors also examined placer gold samples from most major placer deposits in the study area and conducted ore microscopy investigations of the bullion.

Table 3. Heavy mineral identifications from placer concentrate samples, Innoko/Iditarod mining districts, Alaska.*

Map no.	Field no.	Location/description	Heavy minerals	Remarks
1	'Colorado Creek'	From heavy mineral mine concentrates of Lower Colorado Creek placers, Rosander Mining Co.; NE¼, NW¼, Sec. 17, T. 22 S., R. 15 E., K.R.M., Ophir C-1 Quadrangle.	M magnetite, ilmenite, coulsonite, anthophyllite, samarskite; m, tr powellite, xanthoconite	Estimated 50% vol. = magnetite; anomalous PGM in assay derived from gold bullion.
2	81BT529	From heavy mineral concentrate submitted by T. Gates; SW¼, NE¼, Sec. 23, T. 22 S., R. 14 E., K.R.M., Ophir C-1 Quadrangle.	M zircon, magnetite, ilmenite; m, tr coulsonite(?), magnesiochromite	Estimated 65% vol. = zircon
3	'Boob Creek'	From heavy mineral concentrate taken at bottom of shaft during 1983 prospect examination of Sherrer mining operation; SW¼, NW¼, Sec. 17, T. 25 S., R. 10 E., K.R.M., Ophir B-2 Quadrangle.	M magnetite, ilmenite, garnet, cinnabar, magnesiochromite, hematite, zircon; m, tr anthophyllite, cassiterite, diopside, PGM, freegold	Former PGM producer. USGS laboratory analysis indicates platinum metals are ferro-platinum (28).
4	79BT1046	From reconnaissance pan concentrate from mine cut, Dodge Creek, NE¼, SW¼, Sec. 21, T. 27 S., R. 12 E., K.R.M., Ophir B-2 Quadrangle.	M magnetite, ilmenite, siderite, pyrite; m, tr amphibole, pyroxene, zircon	Old mine cut not worked since 1950s.
5	79BT310	From reconnaissance panned concentrate from mine cut near canyon break out of Ophir Creek, Wortman/Roberts operation, NW¼, SW¼, Sec. 23, T. 27 S., R. 12 E., K.R.M., Ophir A-2 Quadrangle.	M magnetite, ilmenite, edenite, zircon, and rutile; m, tr orthoferrosilite, pyrite.	- - -
6	79BT1028	Pan concentrate sample from Tamarack Creek SE¼, NW¼, Sec. 2, T. 28 S., R. 12 E. K.R.M., Ophir A-2 Quadrangle.	M magnetite, ilmenite, pyrite, and pyroxene; tr amphibole and several grains of native silver.	Just above limit of tailings on Spruce Creek.
7	79BT1027	Pan concentrate from bench level, Spruce Creek, NW¼, SW¼, Sec. 2, T. 28 S., R. 12 E., K.R.M., Ophir A-2 Quadrangle.	M magnetite, chromite, ilmenite, orthoferrosilite, riebeckite, tr fluorapatite.	Just downstream from major per-aluminous dike swarm; contains up to 6% chromite by volume.
8	79BT1026	Pan concentrate from Maiden Creek, SW¼, SW¼, Sec. 2, T. 28 S., R. 12 E., K.R.M., Ophir A-2 Quadrangle.	M magnetite, ilmenite, and amphibole; m hypersthene and zircon.	- - -
9	79BT1044	Pan concentrate from mine tailings, Lower Little Creek, SW¼, NW¼, Sec. 5, T. 28 S., R. 13 E., K.R.M., Ophir A-1 Quadrangle.	M magnetite, ilmenite, siderite, monazite; tr pyrite, edenite.	Sample runs 1310 cps on scintillation counter; background is 100 cps.

10	79BT1045	From mine concentrate on Little Creek just below Gold Bottom Creek, NW¼, NE¼, Sec. 7, T. 28 S., R. 13 E., K.R.M., Ophir A-1 Quadrangle.	M magnetite, ilmenite, siderite, enstatite, richterite; m monazite.	Mine records show abundant scheelite; not identified in concentrate here.
11	79BT1043	From mine tailings Lower Ganes Creek near Ophir Road; NE¼, SW¼, Sec. 5, T. 28 S., R. 13 E., K.R.M., Ophir A-1 Quadrangle.	M magnetite, ilmenite, enstatite; m eckermenite.	Anomalous niobium (table 2) unsupported by mineralogy.
12	79BT1042	Pan concentrate from California Creek, SW¼, SW¼, Sec. 14, T. 28 S., R. 13 E., K.R.M., Ophir A-1 Quadrangle.	M magnetite, ilmenite, enstatite, anatase; m, tr rutile, edenite, native silver (2 grains), gold (1 grain). (1 grain).	From previously unmined creek; no production history.
13	79BT1001	Pan concentrate from tailing 1 mile upstream from main camp, Yankee Creek, SE¼, NE¼, Sec. 36, T. 34 N., R. 38 W., S.M., Iditarod D-1 Quadrangle.	M magnetite, ilmenite, magnesiochromite, chlorite, pyrite; m rutile and anatase.	Magnesiochromite - 8% by by volume.
14	79BT4	From heavy mineral concentrate of Rosander placer mine, Yankee Creek SE¼, NW¼, Sec. 3, T. 28 S., R. 13 E., K.R.M., Ophir A-1 Quadrangle.	M magnetite, ilmenite, magnesiochromite (10%), m scheelite, tr freegold.	Concentrate from 1968 mining operation.
15	79BT1035	Pan concentrate from Marten Gulch, tributary Yankee Creek, SW¼, SW¼, Sec. 3, T. 28 S., R. 13 E., K.R.M., Ophir A-1 Quadrangle.	M magnetite, ilmenite, siderite, hornblende, hypersthene; m eckermenite, eckermenite, hidalgoite (lead arsenic sulfate).	- - -
16	79BT1002	From Spaulding Creek near mouth, SW¼, SW¼, Sec. 17, T. 33 N., R. 38 W., S.M., Iditarod D-2 Quadrangle.	M magnetite and ilmenite; m amphibole, and pyroxene.	Poor quality sample.
17	79BT1020	From Independence Creek below mouth of Ready Bullion Creek; SW¼, SW¼, Sec. 19, T. 28 S., R. 14 E., K.R.M., Ophir A-1 Quadrangle.	M magnetite, ilmenite, chlorite; m hornblende, anatase, rutile.	- - -
18	79BT1011	Concentrate from Ready Bullion Creek, NE¼, SE¼, Sec. 25, T. 28 S., R. 13 E., K.R.M., Ophir A-1 Quadrangle.	M magnetite, chlorite, hornblende; m anatase, rutile.	- - -
19	79BT1019	From upper drainage of Independence Creek, SE¼, SE¼, Sec. 31, T. 28 S., R. 14 E., K.R.M., Ophir A-1 Quadrangle.	M magnetite, ilmenite, chlorite; m enstatite, edenite, rutile, anatase.	- - -
20	78BT421	From Steak Creek (draining Takotna Mt.), NE¼, SW¼, Sec. 23, T. 33 N., R. 36 W., S.M., Iditarod D-1 Quadrangle.	M magnetite, ilmenite, m scheelite; tr cinnabar, monazite.	- - -

21	77BT243	From trommel in Candle Creek dredge (abandoned), McGrath D-6 Quadrangle.	M magnesiochromite, zircon, garnet ilmenite; m cinnabar (2%), scheelite (1%); tr olivine and monazite.	Cinnabar retorted for almalgum in past years during mining; anomalous PGM (5.2 ppm) in assays derived from gold bullion.
22	79BT1053	From east flowing tributary, Tatalina River, SE¼, SE¼, SEc. 36, T. 32 N., R. 37 W., S.M., Iditarod D-1 Quadrangle.	M magnetite, ilmenite hyperstene, eckermenite, anatase; m titanite, zircon, fluorapatite.	Drains mineralized zone Mt. Jouquin plutons.
23	79BT1051	Drains unnamed pluton near head of Beaver Creek; in Tatalina River drainage; SW¼, SW¼, Sec. 16, T. 31 N., R. 37 W., S.M., Iditarod D-1 Quadrangle.	M magnetite, eckermenite, enstatite, hastingsite, m anatase, titanite.	- - -
24	79BT1055	Small southerly stream on flank of Mt. Jouquin; NW¼, SW¼, Sec. 31, T. 32 N., R. 37 W., S.M., Iditarod D-1 Quadrangle.	M magnetite, ilmenite, enstatite, crossite; m fluorapatite.	Drains mineralized zone, Mt. Jouquin pluton.
25	79BT1047	From northward tributary of Carl Creek, NE¼, NW¼, Sec. 17, T. 31 N., R. 36 W., S.M., Iditarod D-1 Quadrangle.	M magnetite, galena, ilmenite, crossite; m fluorapatite.	Drains mineralized zone on Tatalina Mt.
26	79BT1050	In easterly drainage of Beaver Creek; SE¼, NE¼, Sec. 4, T. 30 N., R. 37 W., S.M., Iditarod C-1 Quadrangle.	M magnetite, ilmenite, enstatite, anatase; m fluorapatite.	- - -
27	Vinasale Mtn.	From Adler Gulch, south rim of Vinesale Mtn., NE¼, NE¼, Sec. 18, T. 30 N., R. 34 W., S.M., McGrath C-6 Quadrangle.	M magnetite, scheelite, ilmenite, hastingsite, monazite; m, tr native gold, zircon, native bismuth, ilmenorutile.	Sample anomalous in Nb, W, Ce Be, (1,500 ppm), as well as Au; PGM (2.6 ppm) from gold bullion.
28	Tolstoi GT2	From Tolstoi Creek where it bisects early Wisconsin till, NE¼, NW¼, Sec. 2, T. 33 N., R. 41 W., S.M., Iditarod D-3 Quadrangle.	M magnetite, ilmenite, cinnabar, dravite; m, tr chalcopyrite, ilmenorutile, fine gold (40 grains).	- - - anomalous niobium.
29	84BT90	From upper part of drainage below monzonite pluton (Bundtzen and others, 1985); from Magnuson mine cut NW¼, SE¼, Sec. 22, T. 30 N., R. 42 W., S.M., Iditarod C-3 Quadrangle.	M Magnetite, chromite, free mercury, cinnabar; tr polybasite.	Contains 24.8% Cr; paystreak sample submitted for chromite benefication. See table 4.
30	84BT89	From mine cut of Harris operation on Moore Creek, NW¼, SW¼, Sec. 15, T. 29 N., R. 42 W., S.M., Iditarod C-3 Quadrangle.	M magnetite, chromite, zircon; m, tr cinnabar, scheelite, native silver, tetrahedrite.	Mine concentrate ~ 35.0 percent Cr; sample of pay submitted for beneficiation.

31	82BT401	Head of Maybe Creek below cirque, SW¼, SW¼, Sec. 4, T. 30 N., R. 42 W., S.M., Iditarod C-3 Quadrangle.	M chromite, magnesiochromite, cinnabar; m, tr scheelite, free gold (10 grains), polybasite(?).	'New' placer gold occurrence.
32	84BT42	From Wyrick placer mine, in Granite Creek drainage; NE¼, SW¼, Sec. 12, T. 26 N., R. 41 W., S.M., Iditarod B-2 Quadrangle.	M magnetite, ilmenite, zircon, cinnabar, garnet (clear); tr stibnite, cassiterite, abundant gold; at least two generations.	Cassiterite not confirmed by assay.
33	84BT49	Homestake Creek, SE¼, SE¼, Sec. 10, T. 26 N., R. 42 W., S.M. Iditarod B-3 Quadrangle.	M Magnetite, chloritized ilmenite(?), miscellaneous feldspars, tr gold.	Poor sample; few heavy minerals.
34	84BT76	Spruce Creek, George River district, SW¼, SW¼, Sec. 5, T. 24 N., R. 44 W., S.M., Iditarod A-3 Quadrangle.	M magnetite, garnet, ilmenite, chert; m cinnabar fragments.	From mine cut 1980-83.
35	84BT78	Julian Creek placer mine coarse concentrate (Wilmarth Operation), NW¼, NW¼, Sec. 4, T. 24 N., R. 44 W., S.M., Iditarod A-3 Quadrangle.	M zircon, pyrite, cinnabar, barite, magnetite, monazite; m chromite, magnesiochromite, stibnite.	Scintillation counter = 1,200 cps background - 80-120 cps.
36	84BT77	From 1984 mining operation 2 Km above mouth of Julian Creek, SW¼, SE¼, Sec. 35, T. 25 N., R. 44 W., S.M., Iditarod A-3 Quadrangle.	M cinnabar, magnetite, magnesiochromite; m, tr black amphibole, monazite.	- - -
37	84BT96	From right limit bench deposit, Prince Creek, SE¼, SE¼, Sec. 13, T. 26 N., R. 47 W., S.M., Iditarod B-4 Quadrangle.	M zircon, garnet, diopside, tremolite, cinnabar, ilmenite; m, tr chromite, fluorapatite.	- - -
38	84BT97	Prince Creek bench deposit 2 km upstream from #37; SE¼, SW¼, Sec. 12, T. 26 N., R. 47 W., S.M., Iditarod B-4 Quadrangle.	M magnetite, ilmenite, cinnabar, chrome-spinel; m, tr zircon.	- - -
39	84BT98	Cut from modern stream of Prince Creek 1 km above #38; SW¼, NW¼, Sec. 12, T. 26 N., R. 47 W., S.M., Iditarod B-4 Quadrangle.	M cinnabar, ilmenite; m zircon, scheelite, magnetite, diopside, chromite-magnesiochromite.	- - -
40	84BT102e	From Idaho claim near Summit of Chicken Mt., Iditarod district, SW¼, NW¼, SEc. 34, T. 27 N., R. 47 W., S.M., Iditarod B-4 Quadrangle.	M zircon, 'black' pyroxene, amphibole(?); m, tr scheelite, cinnabar.	Zircon = 40% by vol.; White and Killeen (1953) report 0.12% U in zircon near mine site.
41	'Happy Creek'	From Fullerton Mine concentrate near head of Happy Creek, SE¼, SE¼, Sec. 32, T. 27 N., R. 47 W., S.M., Iditarod B-5 Quadrangle.	M zircon, magnetite, ilmenite, chromite, hyperstene, enstatite, richterite; m cinnabar, fluoropatite.	White and Killeen (1953) report up to 0.14% U in zircon from near head of stream.

42	'Black Creek'	From 1981 Miscovich mine concentrate on Lower Black Creek; SW¼, NE¼, Sec. 11, T. 27 N., R. 47 W., S.M., Iditarod B-4 Quadrangle.	M magnetite, ilmenite, cinnabar, chromite, magnesiochromite, scheelite; m richterite, enstatite, zircon, cassiterite, diopside, ilmenorutile; tr argentopyrite.	Platinum metal elements (0.8-1.3 ppm) found during gold fire assay work (table 4)
43	84BT260	From 1984 Lyman mine concentrate on Snow Gulch, SE¼, SE¼, Sec. 14, T. 23 N., R. 49 W., S.M., Iditarod A-5 Quadrangle.	M garnet, cassiterite, calcite; m scheelite, stibnite; tr monazite.	Scintillation counter = 600 cps; background (field) = 120 cps.

* X-ray diffraction augmented by visual inspection techniques by B.C. Cox, (79BT samples and Ophir district), N.C. Veach (mine concentrates from Flat area) and T.K. Bundtzen (mine concentrates in George River, Moore Creek, and Donlin subdistricts). M = >15%, m = 3-15%, tr <3%; made mainly by visual inspection subsequent to X-ray analyses. K.R.M. = Kateel River Meridian; S.M. = Seward Meridian.

List of elements used in table 3

Anatase TiO_2
Anthophyllite $Mg_7Si_8O_{22}OH_2$
Argentopyrite $AgFe_2S_3$
Cassiterite SnO_2
Chalcopyrite $CuFeS_2$
Chlorite MgFe (Al, Si)O(OH)
Chromite $Fe(Cr\ Al)_2\ O_4$
Cinnabar HgS
Coulsonite $FeV_2\ O_4$
Crossite $(NaCaK)_2(FeMgMn)_3(FeAlTi)\ SiAl)\ O_{22}$
Dravite $NaNg_3Al_6B_3Si_6O_{27}(OH_4)$
Diopside $CaMg(Si_2O_6)$
Eckermenite $(Na,K)_3(Fe\ Mg\ Al)_5\ Si_8O_{22}(F,\ OH)_2$
Edenite $NaCaMg_5AlSi_2O_{22}(OH)_2$
Enstatite $MgSiO_3$
Fluorapatite $Ca_5F\ (PO_4)_3$
Galena PbS
Hastingsite $Ca_2NaMg_4Al_3Si_6O_{22}(OH,F)_2$
Hematite Fe_3O_4
Hidalgoite $PbAl_3AsO_4SO_4(OH)_6$
Hypersthene $(Mg\ Fe)\ SiO_3$
Ilmenorutile $Fe(Nb,Ta)\ TiO_2$
Ilmenite $FeTiO_3$
Magnesiochromite $MgCr_2O_4$
Magnetite Fe_3O_4
Monazite $(Ce,La,Y,Th)\ PO_4$
Olivine $(MgFe)_2SiO_4$
Orthoferrosilite
Polybasite $(AgCu)_{16}\ Sb_2S_{11}$
Powellite $CaMoO_4$
Pyrite FeS_2
Richerite $Na_2(MgFe^{2}Fe^{3})_6Si_8O_{22}(OH)_2$
Riebeckite $Na_3Fe_3^{2}Fe_2^{3}Si_8O_{22}(OH)_2$
Rutile TiO_2
Samarskite $(Y,U,Fe)(Nb,Ta,Ti)_2O_6$
Scheelite $CaWO_4$
Siderite $FeCO_3$
Stibnite Sb_2S_3
Titanite (Sphene) $CaTiO(SiO_4)$
Xanthoconite $3Ag_2As_2S_3$
Zircon $ZrSiO_4$

Table 4. Geochemical analyses of pan concentrates, Iditarod and Innoko districts, Alaska (all but platinum in ppm).

Map no.	Field no.	Cu	Pb	Zn	Au	Ag	Mo	Sb	Sn	W	Nb	Ta	As	Co	Ni	Mn	Cr	Pt (ppb)	U	Th	Bi	Y
1a[1]	'Colorado'	175	89	2	2,920	550	83	ND	- -	- -	1,060	23	ND	33	36	763	447	ND	- -	- -	- -	- -
1b	'Colorado'	132	10	19	4,950	816	96	59	- -	12,500	- -	- -	- -	29	24	280	2,500	437	143	49	42	598
2	81BT529	20	1,590	29	10	19	5	5,112	- -	900	- -	- -	- -	1	5	50	100	20	2.0	ND	16	0.5
3	'F [illegible]	357	18	1,600	64	3	27	- -	- -	- -	- -	- -	2,300	- -	- -	- -	- -	ND	- -	- -	- -	- -
·	79BT1046	65	13	146	ND	2	ND	ND	- -	- -	17	3	48	27	67	1,300	60	ND	- -	- -	- -	- -
5	79BT310	67	10	127	ND	2	2	ND	- -	- -			14	19	56	546	92	ND	- -	- -	- -	- -
6	79BT1028	41	8	120	ND	2	2	ND	- -	- -	18	3	23	22	52	633	58	ND	- -	- -	- -	- -
7	79BT1027	39	13	117	ND	1	2	ND	- -	- -	20	11	23	20	55	927	11,500	ND	- -	- -	- -	- -
8	79BT1026	34	13	122	ND	1	2	ND	- -	- -	19	3	ND	23	59	1,380	66	ND	- -	- -	- -	- -
9	79BT1044	62	16	130	2	9	3	ND	- -	- -	19	3	42	25	62	1,530	59	ND	- -	- -	- -	- -
10	79BT1045	62	15	128	ND	2	3	ND	- -	- -	30	3	31	31	60	2,650	41	ND	- -	- -	- -	- -
11	79BT1043	26	11	86	ND	3	3	ND	- -	- -	165	8	ND	13	39	842	92	ND	- -	- -	- -	- -
12	79BT1042	35	11	120	ND	ND	3	ND	- -	- -	- -	- -	ND	21	56	725	54	20	- -	- -	- -	- -
13	79BT1001	22	12	79	ND	9	ND	11	1	1	ND	- -	ND	17	55	972	65	ND	- -	4	- -	- -
15	79BT1035	29	9	94	ND	ND	2	ND					27	14	41	339	40	ND	- -	- -	- -	- -
16	79BT1002	25	10	70	ND	8	ND	ND	1	2			ND	19	60	1,040	65	ND	- -	4	- -	- -
17	79BT1020	24	13	57	ND	8	ND	ND	1	2	ND	- -	22	12	55	485	101	ND	- -	4	- -	- -
18	79BT1011	17	11	74	2	11	2	11	- -	- -	15	3	ND	14	35	757	62	ND	- -	- -	- -	- -
19	79BT1019	23	8	79	ND	2	2	ND	- -	- -	14	3	ND	14	39	385	160	ND	- -	- -	- -	- -
21	77BT235b	42	109	99	520.0	67.3	2	150	- -	- -	- -	- -	ND	16	17	- -	115,000	5,250	15	- -	- -	- -
22	79BT1053	24	8	61	ND	2	2	ND	1	2	39	3	ND	10	26	486	90	ND	- -	- -	- -	- -
23	79BT1051	11	4	71	ND	ND	2	ND	3	2	11	3	ND	12	32	260	65	ND	- -	- -	- -	- -
24	79BT1055	14	4	75	ND	2	2	ND	7	1	12	3	ND	13	35	367	103	20	- -	- -	- -	- -
25	79BT1047	13	5,700	64	ND	23	2	ND	3	1	17	3	ND	ND	21	269	139	ND	- -	- -	- -	500
26	79BT1050	9	7	32	ND	ND	2	ND	1	10	18	7	ND	ND	ND	289	69	ND	- -	- -	- -	- -
27a	82BT200d	11	760	6	21,692	1,598	- -	4,159	- -	88,100	700	5	- -	4	2	112	700	2,624	30	6	28	3
27b	82BT200a	- -	- -	- -	- -	- -	- -	- -	ND	13,700	15	5	- -	- -	- -	- -	- -	ND	- -	- -	- -	- -
27c	82BT200b	- -	- -	- -	- -	- -	- -	- -	10,000	240	15	10	- -	- -	- -	- -	- -	ND	- -	- -	- -	- -
27d	82BT200c	- -	- -	- -	- -	- -	- -	- -	5,000	10,000	15	5	- -	- -	- -	- -	- -	ND	- -	- -	- -	- -
28	'Tolstoi GT2'	21	17	38	8.2	1.0	ND	ND	4	2	218	14	ND	ND	26	283	94	ND	3	10	- -	- -
29	84BT90	40	5	10	513.4	52.7	1	1	- -	300	- -	- -	3	500	300	42	248,000	60	ND	ND	3	8
30	84BT89	- -	- -	- -	14.3	6.1	- -	- -	- -	- -	- -	- -	- -	440	200	- -	350,000	70	- -	- -	- -	- -
34	84BT76	40	25	100	87.3	10.0	ND	ND	10	ND	20		2,000	ND	20	200	30	ND	- -	ND	ND	100
39	84BT98	100	ND	- -	2.0	4.0	- -	- -	- -	500	ND	ND	- -	45	100	- -	- -	ND	- -	- -	50	- -
40	84BT102e	- -	700	140	55.0	9.2	- -	1,000	- -	- -	- -	- -	1,600	- -	- -	- -	- -	ND	- -	- -	110	- -
41	'Happy'	28	ND	35	322.3	42.2	90	62	- -	2,800	10	3	536	12	63	267	600	20	1	5	7	50
42a	'Black'	489	1,433	100	252.0	55.0	15	143	- -	65,100	470	10	6,239	29	86	246	33,500	870	9	12	42	20
42b	'Black'	- -	- -	- -	5.7	13.1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1,300	- -	- -	- -	- -

Analyses of Cu, Pb, Zn, Mo, Sb, As, Co, Ni, and Mn by X-ray fluorescence, DGGS Minerals Laboratory, Fairbanks, Alaska; Au, Ag by fire assay, DGGS Minerals Laboratory, Fairbanks; Sn, Nb, Ta, and W by X-ray fluorescence, Chemex Laboratory, Vancouver, B.C.; Pt, U, Bi, and Y by ICP Geochemical Analysis, ACME Analytical Laboratories, Vancouver, B.C.

__ = Anomalies by inspection.

- - = Not analyzed.

ND = Not detected.

Examination of the gold bullion suggests a number of properties that are consistent throughout the region:

1. Most placer gold is coarse and angular, suggesting minimal stream transport.
2. Cinnabar and quartz are also always found in association with gold grains, thereby suggesting that most placer gold region-wide was derived from low temperature (epithermal) deposits (fig. 3).

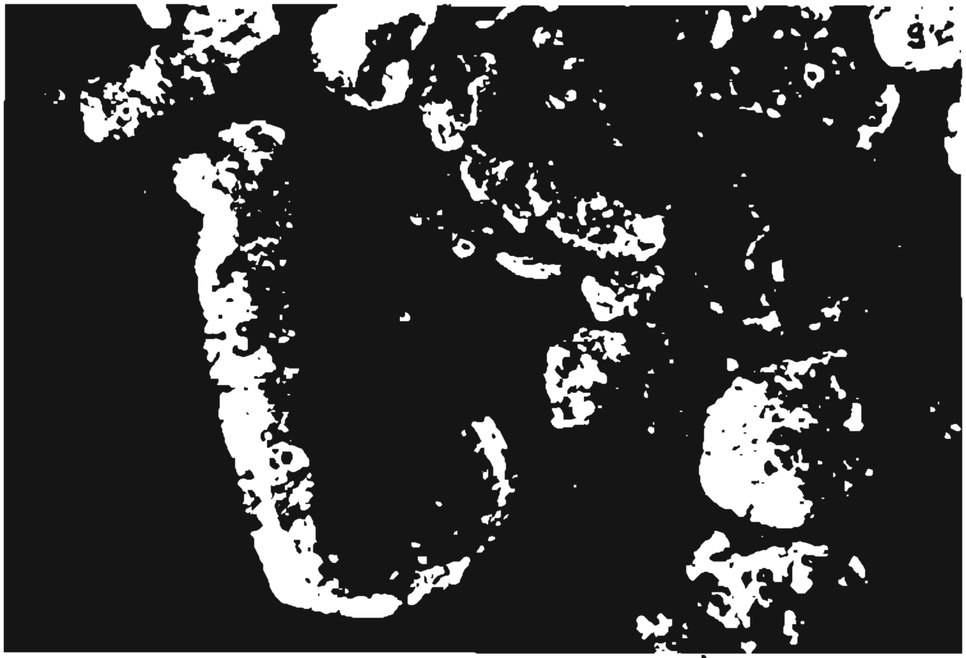

Figure 3. Photomicrograph of gold from Prince Creek, Iditarod district showing gold (g) cinnabar (c) and quartz (q). Field of view = 2 cm.

3. Several types of gold are found in placer deposits. Bench and stream placers from the same drainage usually differ in size, color, and purity, suggesting that 1) different structural levels of the same ore deposits have contributed to placer production through time, 2) different lodes sources have made contributions to the placer deposits.
4. The fineness values of all subdistricts are consistent with those reported by Moiser (40) for epithermal and lower mesothermal temperatures of formation. The highest fineness values in the Innoko/Tolstoi and Iditarod/Donlin regions probably formed at slightly elevated temperatures; higher temperature minerals of tin, molybdenum, and uranium are present in these two regions. The bullion itself was not analyzed for elements other than gold, silver, and platinum; however, the frequent association of gold with antimony and mercury in geochemical work also suggests low temperature conditions of formation for most placers. The Golden Horn lode, which contributed to placer concentrations in Otter and Black Creek, contains gold bullion that precipitated during more than one temperature sequence.
5. Pl tinum Group Metals (PGE) values from 0.8 to 5.4 ppm were obt ined by fire assays of bullion from Colorado Creek (Innoko/Tol oi), Candle Creek (Innoko/Candle), Vinesale Mountain (Inn o/Candle), and Black Creek (Iditarod/Flat). We are unsure,

however, whether PGE is actually in bullion or as discrete grains independent of the placer gold. The presumed lode sources for all but the Colorado Creek locality are meta-aluminous, quartz-alkalic monzonite plutons---the most alkalic plutonic rocks known in the study area. Alkalic plutons are known on a worldwide basis to carry anomalous platinum. Platinum anomalies have been known by miners in the Flat District. According to John Miscovich (22), platinum (in gold bullion) is found in association with zircon-rich concentrates on both Black and Otter Creeks.

The mineralogical associations found in the samples suggest the presence of both multiple and single provenance populations. A summary of provenance indicators by district is summarized in table 5. The following discussions evaluate a number of the mineralogical suites in sample sets. The main platinum anomaly is found in Boob Creek in the Innoko/Tolstoi district where a complex drainage history includes at least two phases of stream piracy. Hence the concentrates in this creek are probably of mixed provenance. The chromite and platinum metals (ferro-platinum) are probably derived from mafic/ultramafic cumulates of presumed Jurassic age at Mt. Hurst (41), 14 km south of Boob Creek, through a captured channel of Ledge Creek. The heavy minerals such as cassiterite, zircon, and garnet, which are more classically associated with felsic igneous rocks may be derived from monzonitic stocks exposed to the east at the headward drainage of Mastodon Creek.

Streams draining monzonitic stocks have yielded niobium-tantalum*, uranium, molybdenum, tin and tungsten minerals. The minerals at Vinesale Mountain, the Beaver Mountains, and the Chicken Mountain area are probably derived from silver-tin-copper-niobium prospects that are known to occur in the headward sources of the drainages. There, tourmaline-axinite-sulfide greisen zones and breccia pipes are localized in cupola zones of stocks and are crudely similar to a Bolivian type of silver-tin-copper mineralization (42). A single pan concentrate from Tolstoi Creek in the Beaver Mountains that contains anomalous niobium and gold in assay and mineral form (28, tables 3, 4) could lead the prospector to such greisen zones some 6 km to the south.

The ubiquitous presence of hypogene chromite in many placer samples is puzzling because much of the accompanying ore mineralogy (i.e. cinnabar, stibnite, silver-sulfosalts) is suggestive of much lower temperature ore formation. Up to 0.5% chromium was detected in mariposite-rich mafic dikes of the Innoko/Ophir district (1); these dikes may be the source of chromite within the local stream drainages. Chromite is so abundant in mine concentrates from the Iditarod/Moore Creek district (29, 30; tables 3, 4) that two bulk samples of virgin pay gravels were collected to evaluate the chromite placer potential. However, table concentrations yielded only 0.2 and 2.2% chromium respectively---too low to be economically significant. The source of chromium in most drainages is speculative. With the exception of the Boob Creek area, there are no known occurrences of ultramafic rocks to account for the concentration of chromite in placer deposits. Other possible sources are 1) monzonitic stocks, which can contain anomalous Cr values in the 300-800 ppm range;

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* Geochemica analyses (table 4) seem to indicate that the niobium end member prec minates in the Nb-Ta minerals ilmenorutile and samarskite (table 3).

Table 5. Summary of heavy mineral placer data, Innoko and Iditarod districts, Alaska.

Subdistrict	Geology of presumed lode source	Gold fineness	Major and minor heavy minerals	Anomalies; remarks
Innoko/Tolstoi	Meta-aluminous alkali/calcic to quartz alkalic Mesozoic plutons of monzonitic composition	897 (N = 6)	Zircon, magnetite, ilmenite, samarskite, powellite, xanthoconite, cassiterite	Platinum in gold bullion at Colorado Creek; tin, niobium, molybdenum, and uranium mineralogy; silver sulfides.
Innoko/Ophir	Bimodal dike swarms; gold mainly from per aluminous rhyolite with contribution from alkali-calcic monzonite on Yankee Creek	853 (N = 13)	Magnetite, cinnabar, chromite or magnesite chromite, scheelite, monazite, ilmenorutile, native silver	Scheelite very abundant in Little Creek.
Innoko/Candle	Meta-aluminous quartz alkalic monzonitic plutons in Candle Hills and at Vinesale Mt.	914 (N = 3)	Magnetite, magnesiochromite, cinnabar, olivine, ilmenorutile, sodic amphibole scheelite.	Anomalous platinum in gold bullion; niobium end member in ilmenorutile.
Iditarod/Moore	Meta-aluminous alkalic-calcic plutons of monzonitic composition.	836 (N = 3)	Chromite, cinnabar, native silver, and silver sulfosalts.	Highest silver/gold ratio of any district.
Iditarod/George	Both meta-aluminous alkalic/calcic monzonite and peraluminous rhyolite (very similar to Innoko/Ophir).	853 (N = 4)	Magnetite, garnet, cinnabar, stibnite, monzonite.	Julian Creek has most radioactive concentrates of all examined.
Iditarod/Flat	Quartz alkalic meta-aluminous gabbro-to-monzonite plutons.	867 (N = 12)	Cinnabar, chromite, zircon ilmenorutile, scheelite, cassiterite.	Platinum in gold bullion; uranium in zircon.
Iditarod/Donlin	Peraluminous rhyolite dikes.	922 (N = 3)	Garnet, cassiterite, stibnite, monazite.	Radioactive concentrates similar to Julian Creek.

2) olivine-bearing alkali basalts which contain background chrome values similar to those of the monzonite plutons; 3) remnants of Tertiary gravels containing mineralogy from distal ultramafic source rocks---perhaps the Dishna ophiolite to the west (Marti Miller (43)). The first two possibilities are favored by the authors because of the nearly ubiquitous presence of volcanic/plutonic complexes in areas of chromite concentration.

Scheelite from streams in the Chicken Mountain area (Iditarod/Flat) is probably derived from known upstream hardrock sources such as the Golden Horn deposit. However, lode sources for abundant scheelite in other areas such as Little, Yankee, and Alder Creeks (Innoko District) have not been found.

Alkali-enriched amphiboles and pyroxenes including eckermanite, hastingsite, edenite, richterite, and riebeckite are locally abundant in concentrates draining the monzonite plutons of the study area. These data serve as indirect but corroborative evidence not only that the stocks are undersaturated with respect to quartz but also demonstrate alkaline affinities for the LK-ET igneous suite. The sodium-enriched minerals riebeckite and hastingsite generally occur in alkaline provinces worldwide. The alkali-enriched pyroxene and amphiboles had not been identified during initial thin section studies of igneous rocks, but subsequent laboratory work has established their presence in mainly monzonitic plutons in the Flat, Moore and Candle camps.

Concentrates throughout the region, both those associated with peraluminous rhyolites as well as monzonitic stocks, are consistently radioactive. Radioactive zircon (up to 0.14%U) was reported from the Flat area (9) and we describe several uranium/thorium minerals here. Seven bulk samples of plutons from the Innoko District contain 7.1 to 16.4 ppm uranium and 15 to 24 ppm thorium, some of the highest background values for an igneous suite known in the state (1, 44). However, specific lode sources for radioactive minerals found during our investigation remain unknown.

Conclusions

Although many questions remain unanswered, the heavy mineral concentrate data, coupled with knowledge of lode and placer geology, provide important prospecting guides in the area. Prospecting the cupola phases of the volcanic-plutonic complexes may lead to the discovery of new lode deposits of 1) gold-mercury-antimony, 2) Bolivian type tin-silver-copper, 3) arsenic-tungsten-gold, and 4) niobium-tantalum-rare earth elements associated with the above. Elevated platinum levels associated with some placer gold suggests the potential for gold-platinum-copper occurrences within the quartz alkalic plutonic suite. The sampling effort demonstrates that lode sources and their host igneous rock suites in the study area can be better classified and assessed for a variety of elements previously unrecognized.

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25