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MAGNETIC MEDIA FILE OF ANALYTICAL RESULTS AND GEOCHEMICAL SIGNATURES OF LODE GOLD, PLACER GOLD, AND HEAVY-MINERAL CONCENTRATES FROM MINING DISTRICTS IN CENTRAL, WESTERN, AND NORTHERN ALASKA

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INTRODUCTION

A study of gold-producing districts in Alaska was begun by the U.S. Geological Survey (USGS) Branch of Geochemistry (BGC) in 1982 and continued with participation of the Alaska Division of Geological and Geophysical Surveys (ADGGS) beginning in 1983. The objectives of the study were to (1) chemically characterize samples of native gold from active mines; (2) determine relationships of gold in placer deposits to possible lode sources; (3) chemically characterize the deposits; (4) identify possible sources of gold in placer deposits; (5) study processes of placer formation; (6) contribute to existing knowledge of the principles of prospecting for placer deposits; and (7) determine whether concentrates from mining operations contain valuable commodities in addition to gold. The purpose of this report is to release both the analytical data and gold signatures for placer and lode gold and also the analytical data of associated heavy-mineral concentrates on magnetic media (floppy disk) suitable for entry into a personal computer. Gold signatures comprise the alloy proportions and ratios of gold, silver, and copper, and the content of trace elements (Antweiler and Campbell, 1976).

SAMPLING AND ANALYTICAL METHODS

Two types of samples were collected and analyzed: (1) native gold, and (2) concentrates of alluvium or mineralized rock from mines and prospects. Native gold was usually obtained from concentrates by panning and hand picking with the aid of a binocular microscope; in some instances, miners donated native gold which they had already removed from their concentrates. Most of the concentrates of alluvium were from sluices, and most of the concentrates from crushed mineralized rock were obtained by hand panning.

Emission spectrographic analyses using a technique described by Mosier (1975) were made on 3,238 native gold samples collected from mining districts of central and northern Alaska. Spectrographic results were obtained by visual comparison of spectra derived from the sample against spectra obtained from standards made from pure oxides, graphite, and 99.999 percent metallic gold. Pure Al_2O_3 was added to the standards and samples as a co-distillation agent. Standard concentrations are geometrically spaced over any given order of magnitude of concentration as follows: 100, 50, 20, 10, and so forth. Samples whose concentrations are estimated to fall between those values are assigned values of 70, 30, 15, and so forth. Standard concentrations are based on a 5-mg gold sample weight. Because of the nature of native gold, it is often difficult to weigh precisely 5-mg samples; and in many instances there was less than 5-

mg of gold available for analysis. When sufficient gold was available from a particular site, multiple analyses were made and results listed. Therefore, the determined concentration values were proportionally corrected and are reported to reflect a 5-mg sample weight by the following formula:

$$\text{reported concentration value} = \text{determined value} \times \frac{5}{\text{sample weight}}.$$

The trace-element content of natural gold ranges widely from grain to grain as well as from deposit to deposit and this creates a problem in determining the precision of the analytical technique. However, studies using artificial melts show that the precision of the analytical method far exceeds the natural variability of trace elements in native gold (Mosier, 1975).

Rosenblum and others (1986) report that in the Goodnews Bay, area of Alaska platinum group elements PGE minerals may occur as discrete grains in magnetic concentrates and as inclusions in magnetite, and that the fine-grained fraction of concentrates contain the greatest amount of PGE. They also report that fine grinding of magnetite before fusion produced increases in recovered PGE, perhaps indicating some type of chemical losses during fusion of coarser grains of magnetite. Therefore, the concentrate samples of alluvium were air dried and pulverized to a powder consistency and the mineralized rocks were crushed, hand panned, and pulverized to a powder consistency in the laboratory. These 564 concentrate samples were then analyzed for 34 elements using a semiquantitative, direct-current arc emission spectrographic method (Grimes and Marranzino, 1968). As with the analytical method for gold, spectrographic results were obtained by visual comparison of spectra derived from samples against spectra obtained from standards made from pure oxides and carbonates with the same geometrical interval spacing of concentrations. The precision of the analytical method for the nonmagnetic fraction is approximately plus or minus one reporting interval at the 83 percent confidence level and plus or minus two reporting intervals at the 96 percent confidence level (Motooka and Grimes, 1976).

Fire-assay analyses for the six PGE were performed on the pulverized alluvium and the mineralized rock concentrates. The fire-assay procedure consists of a nickel sulfide fusion and an inductively coupled plasma-mass spectrometric (ICP-MS) detection system. The method is currently being used in USGS Branch of Geochemistry laboratories in Denver, Colorado. Determinations of PGE in standards have shown the method yields reproducible results. When available, several 10-g splits were analyzed as replicates from the same sample.

Table 1 lists the lower limits of determination for emission spectrographic analysis and fire-assay/ICP mass spectrographic analysis.

RELIABILITY OF GOLD ANALYSES

Differences in the composition of native gold from different geological settings can readily be distinguished using the analytical procedure mentioned above if enough analyses are made to ascertain the magnitude of natural variations in gold samples or provide a good estimate of mean values. In this study five or more spectrographic analyses were found to be desirable for a single sample site to obtain a signature in which one can place confidence. However, in the context of many other analyses from a district, a single analysis is of value, and three analyses at a sample site are sufficient.

The composition of native gold varies considerably (Gay, 1963; Jones and Fleischer, 1969) and variations in composition are present even from point to point within the same grain (Desborough, 1970). Native gold in oxidized zones and in associated placers generally contains lesser amounts of silver and other elements compared with the native gold in the corresponding primary deposits; within such specific deposits, single particles of native gold are relatively homogeneous, but in other deposits single particles of native gold are heterogeneous (Boyle, 1979). Variations in gold composition are natural rather than analytical, as such they are worthy of study in order to understand their significance, In spite of the variations, gold compositional data are useful in that they help characterize conditions of ore deposition and commonly are locally distinctive for mines, districts, or regions. Moreover, they are useful in determining the relationships of gold in placer deposits to possible lode sources, and in meeting objectives stated in the introductory section of this report.

The natural variability of analyses for Ag and Cu in gold from a single locality was determined by repeatedly analyzing portions of single nuggets (Mosier, 1975; Antweiler and Campbell, 1987). They found the silver content of one such nugget ranged from 4.7 to 8.1 percent in four analyses with a standard deviation of ±1.6 percent and the copper content of this nugget ranged from .048 to .08 percent with a standard deviation of ±.0144 percent. Replicate analyses of portions of another nugget from the same locality showed silver content of 18.9 to 19.8 percent with a standard deviation of ±0.56 percent and copper content .038 to .055 percent with a standard deviation of ±.012 percent. Such analytical results indicated considerable natural variability. Another nugget from the same locality was washed with hydrofluoric acid to remove surface coatings, then heated to 1300°C for 30 minutes to homogenize the silver and copper content. Analysis of ten 5-mg portions of that nugget each time showed excellent precision; 10 percent silver, (S.D.=0) and 0.05 percent copper (S.D.=0). Prior to acid washing and heat treating, ten 5-mg portions ranged in silver content from 1.5 to 15 percent and in copper content from .015 to .05 percent indicating their natural variation (Mosier, 1975). The concentration of other elements in nuggets from the locality ranged somewhat more widely than copper and silver, even after the homogenization treatment. Significantly, however, the mean values for most elements, including copper and silver, were almost the same on 10 analyses of the natural sample as the mean values for those elements on the homogenized sample, except for elements removed by the acid and heat treatment.

Accuracy is much more difficult to determine than precision because homogeneous gold samples with known amounts of impurities are not readily available. However, standards prepared with known amounts of copper and silver show the method to be accurate within a factor of two in determination of those elements (Mosier, 1975).

One test for reliability of the method is comparison of fineness on samples from localities where large lots of gold have been analyzed for the U.S. Mint or by banks or commercial refiners who have purchased gold. Compilations of gold fineness data have been made by Smith (1941) and by Metz and Hawkins (1981). The First National Bank in Fairbanks made available to us records of gold purchases from 1903 to 1937 from many Alaskan placer deposits. These compilations show excellent agreement with each other for some areas and poor agreement in other areas. The U.S. Geological Survey data, although acquired by analyses of relatively small samples, agree with the data from those sources and are therefore reliable only to the extent permitted by natural variation of gold composition.

DESCRIPTION OF GOLD DATA FILE

The gold data magnetic media file contains 3,238 analyses with 52 attributes. The beginning of the file shows the 52 attributes pertaining to each sample. The attributes are as follows:

	Attribute	Description/Explanation
1	Latitude	Degree, minute, second
2	Longitude	Degree, minute, second
3	District	Mining district(s) or 1:250,000 scale quadrangle (See appendix A)
4	Lo/Pl	Lode gold sample or placer gold sample 1 = lode 2 = placer
5	Site Type	Site—Sample site for respective mining district(s) or 1:250,000 scale quadrangle is the whole portion of the number given. Type—Refers to the physical attributes of the gold analyzed (See appendix A) and is coded by the fractional portion of the number given
6	Gold	Sample classification 1 = Au sample 2 = Pt sample ($Pt \geq 40\%$) 3 = Ag sample ($Ag \geq 45\%$) 0.0 B = unknown sample
7	Au%	$Au\% = 100 - (Ag\% + \text{Sum of } X\%)$
8	Fineness	$\frac{Au\%}{Au\% + Ag\%} \times 1{,}000$
9, 11-47	Ag%, Cu%–Si%	Weight percent of element
10	Sum X%	Sum of elements percent other than Au and Ag
48	Smpl Wt	Sample weight in milligrams
49	r = Au/Ag	Alloy ratio that are part of a gold signature (Antweiler and Campbell, 1976)

50	Au/Cu	do.
51	Ag/Cu	do.
52	r/Cu	do.

Each sample is in the following format:

1	Sample number
2	Sample ID
3	Laboratory tag number
4	Latitude in degrees, minutes, and seconds
5	Longitude in degrees, minutes, and seconds

The following numbers are in scientific notation format:

6	Latitude in decimal degrees
7	Longitude in decimal degrees
8	District and (or) quadrangle identifier number
9	Lode gold or placer gold identifier number
10	Sample site number and type of gold analyzed
11	Sample classification
12	Au%
13	Ag%—Emission spectrographic analysis, results in weight percent
14	Gold fineness
15	Sum of X (sum of element's percent other than Au + Ag)
16	Cu—Emission spectrographic analysis, results in weight percent
17	Zn—Emission spectrographic analysis, results in weight percent
18	Ga—Emission spectrographic analysis, results in weight percent
19	Pb—Emission spectrographic analysis, results in weight percent
20	As—Emission spectrographic analysis, results in weight percent
21	Sb—Emission spectrographic analysis, results in weight percent
22	Cd—Emission spectrographic analysis, results in weight percent
23	Bi—Emission spectrographic analysis, results in weight percent
24	Hg—Emission spectrographic analysis, results in weight percent
25	Te—Emission spectrographic analysis, results in weight percent
26	Ni—Emission spectrographic analysis, results in weight percent
27	Co—Emission spectrographic analysis, results in weight percent
28	Sn—Emission spectrographic analysis, results in weight percent
29	Mo—Emission spectrographic analysis, results in weight percent
30	Ge—Emission spectrographic analysis, results in weight percent
31	Pt—Emission spectrographic analysis, results in weight percent
32	Pd—Emission spectrographic analysis, results in weight percent
33	Ba—Emission spectrographic analysis, results in weight percent
34	Sr—Emission spectrographic analysis, results in weight percent
35	Zr—Emission spectrographic analysis, results in weight percent
36	V—Emission spectrographic analysis, results in weight percent
37	Cr—Emission spectrographic analysis, results in weight percent

38	Y—Emission spectrographic analysis, results in weight percent
39	La—Emission spectrographic analysis, results in weight percent
40	Sc—Emission spectrographic analysis, results in weight percent
41	Nb—Emission spectrographic analysis, results in weight percent
42	B—Emission spectrographic analysis, results in weight percent
43	Ta—Emission spectrographic analysis, results in weight percent
44	In—Emission spectrographic analysis, results in weight percent
45	Be—Emission spectrographic analysis, results in weight percent
46	W—Emission spectrographic analysis, results in weight percent
47	Mn—Emission spectrographic analysis, results in weight percent
48	Fe—Emission spectrographic analysis, results in weight percent
49	Mg—Emission spectrographic analysis, results in weight percent
50	Ca—Emission spectrographic analysis, results in weight percent
51	Ti—Emission spectrographic analysis, results in weight percent
52	Si—Emission spectrographic analysis, results in weight percent
53	Sample weight in milligrams
54	r = Au/Ag
55	Au/Cu
56	Ag Cu
57	r/Cu

An analytical value of zero "B" (0.0 B) indicates that a given element was looked for but not detected at the lower limit of determination shown for that element in table 1.

Because the sample weight often varies from the 5-mg weight designed for the analytical method and because these are computer-generated data, the analytical results listed in the data often carry nonsignificant digits to the right of the significant digits. The analysts did not determine these values to the accuracy suggested by the extra numbers.

DESCRIPTION OF CONCENTRATE DATA FILE

The concentrate data file from alluvium or mineralized rock from mines and prospects contains 564 analyses and 49 attributes on magnetic media. The beginning of the file shows the 49 attributes pertaining to each sample. The attributes are as follows:

	Attribute	Description/Explanation
1	Latitude	Degree, minute, second
2	Longitude	Degree, minute, second
3	District	Mining district(s) and (or) 1:250,000-scale quadrangle
4	Lo/Pl	Source of concentrate 1 = lode (mineralized rock) 2 = placer alluvium

5	Site	Sample site for respective mining district(s) or 1:250,000-scale quadrangle (See appendix A)
6-11	Fe%, Mg%, Ca%, Ti%, Na%, and P%	Emission spectrographic analysis, results in weight percent

12-42	Mn, Ag, As, Au, B, Ba, Be, Bi, Cd, Co, Cr, Cu, La, Mo, Nb, Ni, Pb, Sb, Sc, Sn, Sr, V, W, Y, Zn, Zr, Th, Ga, Ge, Pd, and Pt	Emission spectrographic analysis, results in parts per million
43-48	As-Pt, As-Pd, As-Rh, As-Ru, As-Os, and As-Ir	Fire-assay ICP mass spectrographic analysis, results in parts per million
49	Samp Wt	Emission spectrographic analysis on 5-mg sample and fire-assay mass spectrographic analysis based on 10-g sample

Each sample is in the following format:

1	Sample number
2	Sample ID
3	Laboratory tag number
4	Latitude in degrees, minutes, and seconds
5	Longitude in degrees, minutes, and seconds

The following numbers are in scientific notation:

6	Latitude in decimal degrees
7	Longitude in decimal degrees
8	District and (or) quadrangle identifier number
9	Source of concentrate identifier number
10	Sample site number
11	Fe%—Emission spectrographic analysis
12	Mg%—Emission spectrographic analysis
13	Ca%—Emission spectrographic analysis
14	Ti%—Emission spectrographic analysis
15	Na%—Emission spectrographic analysis
16	P%—Emission spectrographic analysis
17	Mn ppm—Emission spectrographic analysis
18	Ag ppm—Emission spectrographic analysis
19	As ppm—Emission spectrographic analysis
20	Au ppm—Emission spectrographic analysis
21	B ppm—Emission spectrographic analysis
22	Ba ppm—Emission spectrographic analysis
23	Be ppm—Emission spectrographic analysis
24	Bi ppm—Emission spectrographic analysis
25	Cd ppm—Emission spectrographic analysis
26	Co ppm—Emission spectrographic analysis
27	Cr ppm—Emission spectrographic analysis
28	Cu ppm—Emission spectrographic analysis

29	La ppm—Emission spectrographic analysis
30	Mo ppm—Emission spectrographic analysis
31	Nb ppm—Emission spectrographic analysis
32	Ni ppm—Emission spectrographic analysis
33	Pb ppm—Emission spectrographic analysis
34	Sb ppm—Emission spectrographic analysis
35	Sc ppm—Emission spectrographic analysis
36	Sn ppm—Emission spectrographic analysis
37	Sr ppm—Emission spectrographic analysis
38	V ppm—Emission spectrographic analysis
39	W ppm—Emission spectrographic analysis
40	Y ppm—Emission spectrographic analysis
41	Zn ppm—Emission spectrographic analysis
42	Zr ppm—Emission spectrographic analysis
43	Th ppm—Emission spectrographic analysis
44	Ga ppm—Emission spectrographic analysis
45	Ge ppm—Emission spectrographic analysis
46	Pd ppm—Emission spectrographic analysis
47	Pt ppm—Emission spectrographic analysis
48	As-Pt ppm—Fire-assay ICP mass spectrographic analysis
49	As Pd ppm—Fire-assay ICP mass spectrographic analysis
50	As-Rh ppm—Fire-assay ICP mass spectrographic analysis
51	As-Ru ppm—Fire-assay ICP mass spectrographic analysis
52	As-Os ppm—Fire-assay ICP mass spectrographic analysis
53	As-Ir ppm—Fire-assay ICP mass spectrographic analysis
54	Sample weight

A letter "N" with the numeric portion of the analytical value indicates that a given element was looked for but not detected at the lower limit of determination shown for that element in table 1. If an element was observed but below the lowest reporting value the letter (L) was entered in the data with the lower limit of determination. If an element was observed but was above the highest reporting value the letter (G) was entered in the data with the upper limit of determination. If an element was not analyzed for in a sample, an analytical value of zero "B" (0.0 B) was entered.

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Table 1. Lower limits of analytical determination for the emission spectrographic analysis of native gold and heavy-mineral-concentrate samples based on a 5-mg sample and fire-assay ICP mass spectrographic analysis of heavy-mineral-concentrate samples based on a 10-g sample

[--, indicates element not analyzed by this method]

	Emission spectrographic analyses		Fire-assay ICP mass spectrographic analysis
Chemical symbol–element name	Native gold	Heavy-mineral concentrate	Heavy-mineral concentrate
	weight percent	weight percent	parts per million
Ca – Calcium	0.001	0.1	--
Fe – Iron	.001	.1	--
Mg – Magnesium	.0001	.05	--
Ti – Titanium	.001	.005	--
Na – Sodium	--	.5	--
P – Phosphorous	--	.5	--
		parts per million	
Ag – Silver	.001	1	--
As – Arsenic	.005	500	--
Au – Gold	--	20	--
B – Boron	.0005	20	--
Ba – Barium	.0005	50	--
Be – Beryllium	.0001	2	--
Bi – Bismuth	.0002	20	--
Cd – Cadmium	.0002	50	--
Co – Cobalt	.0005	20	--
Cr – Chromium	.001	20	--
Cu – Copper	.0005	10	--
Ga – Gallium	.0002	10	--
Ge – Germanium	.0005	20	--
Hg – Mercury	.002	--	--
In – Indium	.0005	--	--
Ir – Iridium	--	--	0.0005
La – Lanthanum	.002	100	--
Mn – Manganese	.0001	20	--
Mo – Molybdenum	.0005	10	--
Nb – Niobium	.001	50	--
Ni – Nickel	.0005	10	--
Os – Osmium	--	--	0.001
Pb – Lead	.0002	20	--
Pd – Palladium	.0002	5	0.0008

Table 1. Continued

Chemical symbol–element name	Emission spectrographic analyses		Fire-assay ICP mass spectrographic analysis
	Native gold	Heavy-mineral concentrate	Heavy-mineral concentrate
	weight percent	parts per million	parts per million
Pt – Platinum	.001	20	.0005
Rh – Rhodium	--	--	.0005
Ru – Ruthenium	--	--	.0005
Sb – Antimony	.002	200	--
Si – Silicon	.0002	--	--
Sc – Scandium	.0005	10	--
Sn – Tin	.0005	20	--
Sr – Strontium	.01	200	--
Ta – Tantalum	.005	--	--
Te – Tellurium	.005	--	--
Th – Thorium	--	200	--
V – Vanadium	.001	20	--
W – Tungsten	.005	50	--
Y – Yttrium	.0005	20	--
Zn – Zinc	.005	500	--
Zr – Zirconium	.0005	20	--

Appendix A.

Key and explanation for attribute 3 (District) and the fractional portion of attribute 5 (Type) of the gold data magnetic media file.

Attribute 3 (District)

District	Mining district(s) and (or) 1:250,000-scale quadrangles
1.00	Koyakuk-Chandalar mining districts
2.00	Manley Hot Springs, Tofty, Eureka, and Rampart mining districts
3.00	Tolovana (Livengood) mining district
4.00	Circle mining district
5.00	Fortymile mining district
6.00	Bonnifield mining district
7.00	Fairbanks mining district
8.01	Bendeleben 1:250,000-scale quadrangle
8.02	Candle 1:250,000-scale quadrangle
8.03	Nome 1:250,000-scale quadrangle
8.04	Solomon 1:250,000-scale quadrangle
8.05	Teller 1:250,000-scale quadrangle
9.01	Anchorage 1:250,000-scale quadrangle
9.02	Charley River 1:250,000-scale quadrangle
9.03	Healy 1:250,000-scale quadrangle
9.04	Iditarod 1:250,000-scale quadrangle
9.05	Juneau 1:250,000-scale quadrangle
9.06	Mt. Hayes 1:250,000-scale quadrangle
9.07	Mt. McKinley 1:250,000-scale quadrangle
9.08	Ophir 1:250,000-scale quadrangle
9.09	Ruby 1:250,000-scale quadrangle
9.10	Talkeetna 1:250,000-scale quadrangle

Fractional portion of attribute 5 (Type)

To determine whether differences in composition could be correlated with physical attributes, the gold samples were handled in various ways. Some were sieved into two or more size ranges; other were separated by color; and some were separated on the basis of physical characteristics, e.g., rounded, blocky, delicate, etc. Self-explanatory, descriptive physical attributes of the 3,238 gold samples analyzed are provided in U.S. Geological Survey open-file reports listed below. Where no descriptive information is provided, the samples were generally small, and no sorting of individual grains was attempted prior to analysis.

District	**U.S. Geological Survey open-file reports**
1.00	83-345 (Mosier, E.L., and others, 1986)
2.00	88-443 (McDanal, S.K., and others, 1988)
3.00	88-578 (Cathrall, J.B., and others, 1988)
4.00	88-676 (Cathrall, J.B., and others, 1988)
5.00	89-451 (Cathrall, J.B., and others, 1989)
6.00	89-461 (Cathrall, J.B., and others, 1989)
7.00	89-490 (Cathrall, J.B., and others, 1989)
8.01-8.05	91-348 (Cathrall, J.B., and others, 1991)
9.01-9.10	90-210 (Cathrall, J.B., and others, 1990)
	Other publications
1.00	Mosier, E.L., Cathrall, J.B., Antweiler, J.C., and Tripp, R.B., 1989, Geochemistry of placer gold, Koyukuk-Chandalar mining district, Alaska: Journal of Geochemical Exploration, v. 31, no. 3, p. 97-115.