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Source and Bedrock Distribution of Gold and Platinum-Group Metals in the Slate Creek Area, Northern Chistochina Mining District, East-Central Alaska

By: Jeffrey Y. Foley and Cathy A. Summers

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	pct	percent
lb	pound	ppb	parts per billion
mi	mile	ppm	parts per million
oz	troy ounce	yd^3	cubic yard
oz/st	troy ounce per short ton		

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SOURCE AND BEDROCK DISTRIBUTION OF GOLD AND PLATINUM-GROUP METALS IN THE SLATE CREEK AREA, NORTHERN CHISTOCHINA MINING DISTRICT, EAST-CENTRAL ALASKA

By Jeffrey Y. Foley[1] and Cathy A. Summers[2]

ABSTRACT

Placer gold and platinum-group metals (PGM) in the Slate Creek area, northern Chistochina Mining District, are derived from silicified and carbonate-altered, Cretaceous-Tertiary (?) dikes and related mafic and ultramafic rocks. Gold in the placer deposits is also derived from Tertiary conglomerate and altered Jurassic-Cretaceous argillite. The argillite and igneous bedrock sources show a unique Ag-Au-Cu-Hg-PGM association that is attributed to a combination of magmatic, hydrothermal, and supergene processes. The bedrock and placer deposits contain a variety of gold-silver-lead-copper and PGM alloys. The observed geochemical, mineralogic, and alteration features are consistent with current geological models for turbidite-hosted gold deposits. No economic gold or PGM lodes were identified, but several areas warranting more detailed investigation were identified.

Conventional geochemical sampling and analysis of small sample splits weighing between 10 and 30 grams were shown to be unreliable as a consistent means of identifying gold- and PGM-bearing bedrock. Pan concentration of pulverized rock samples was shown to be a more effective, but still imperfect means of identifying gold and PGM source rocks. Geochemical data and mineralogic examination indicate that gold and PGM in potential lode sources are very finely and erratically disseminated, are chemically combined with other elements, and may not be entirely free-milling or amenable to simple gravity concentration.

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INTRODUCTION

Since World War II, the Bureau of Mines has intermittently investigated strategic and critical mineral resources in Alaska. Strategic and critical minerals include those minerals for which the nation relies upon foreign and potentially unreliable sources. Since 1981, the Fairbanks Section of the Bureau's Alaska Field Operations Center (AFOC) has investigated chromium, tin, tantalum, columbium (niobium), rare-earth element, platinum-group metals (PGM), and other strategic and critical mineral resources in Alaska. This report summarizes the Bureau's mineral investigations in the upper Chistochina Mining District, in the east-central Alaska Range where, since World War I, minor amounts of PGM have been recovered as a consequence of placer gold mining. The east-central Alaska Range contains numerous other PGM occurrences in a variety of geologic settings. This investigation is part of a broader study, by the Bureau, of PGM resources in the Alaska Range.

Field work during the present investigation was conducted during several one- to two-week periods, beginning in 1984 and ending in 1988. No field work was done in the area in 1986. The field work was conducted primarily on foot from a camp site at the mouth of Miller Gulch. Helicopter-supported traverses were conducted during three days in 1988.

ACKNOWLEDGMENTS

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Mine property owners and operators in the study area also provided invaluable assistance and support in conducting this investigation. Messrs. William Beerman, Big Four Gulch owner and operator, Yakima (WA), George Cochetas, Slate Creek-Ruby Gulch owner and operator, Golden (Co), Howard Hayes, Miller Gulch claim owner, Douglas (AK) and Dan Livermore, mine operator, Anchorage (AK), donated PGM, gold, and placer concentrate samples and provided continuous logistical support during the Bureau's field investigations.

In addition to review of this report by other Bureau employees, critical reviews were also performed by T.K. Bundtzen of the Alaska Division of Geological and Geophysical Surveys and T.D. Light, U.S. Geological Survey.

LOCATION, ACCESS AND LAND STATUS

The study area (fig. 1) is in the Chistochina Mining District (31)[3], 180 mi southeast of Fairbanks, in the southeastern part of the U.S. Geological Survey Mt. Hayes Quadrangle. The area is between 63°09' and 63°12' latitudes and between 144°43' and 144°54' longitudes. Ice-covered, 10,300-ft-high Mt. Kimball is located 6 mi northeast of the study area, and is the highest mountain in the eastern Alaska Range. The study area lies between the 3,600- and 6,100-ft elevations and is characterized by moderately-steep slopes that are generally negotiable on foot.

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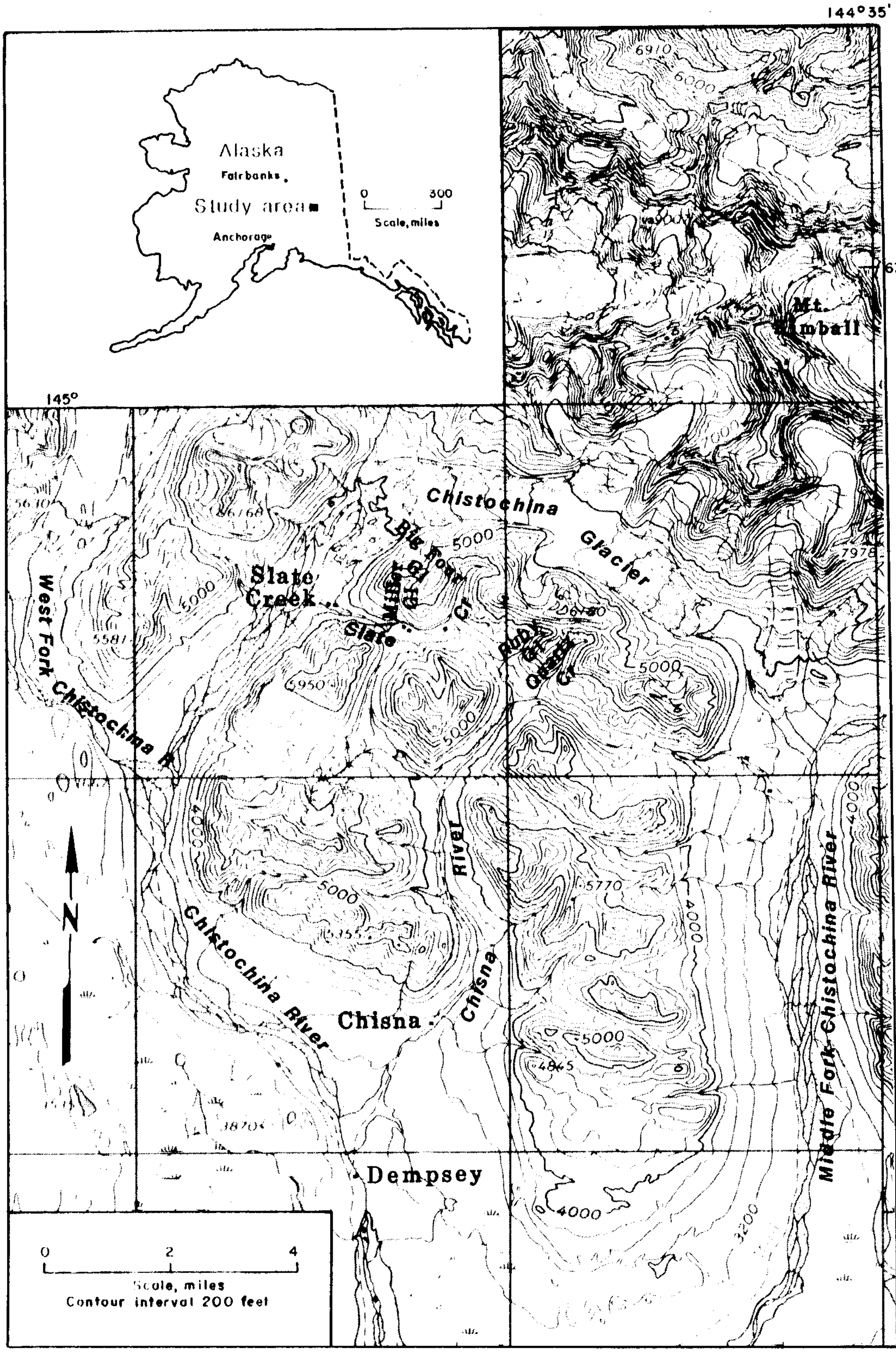
[3] Underlined numbers in parentheses refer to items in the list of references at the end of this report.



Base adapted from U.S.G.S. Mt. Hayes 1:250,000 quadrangle

Figure 1. - Map of Slate Creek and surrounding area in the northern Chistochina Mining District.

Access to the study area is possible by fixed-wing aircraft to either of two primitive airstrips in the Slate Creek-Chisna River area. Another airstrip is located on patented mining claims along the Chistochina River Valley, at the mouth of Slate Creek.

There are no established roads connecting the area to the Alaska Highway system, but overland travel along several winter routes has been used in the past to haul fuel and mining equipment into the area. A winter trail provides access to the area from the community of Chistochina on the Tok Cutoff Highway. That trail covers a distance of 38 mi to the abandoned community of Dempsey on the Chistochina River. At Dempsey the trail bifurcates, and reaches the Slate Creek Valley by either proceeding up the Chisna River to Ruby Creek and over the divide to Slate Creek or, up the Chistochina River to the mouth of Slate Creek. Use of this trail requires snow removal and construction of ice bridges on the Chistochina and Chisna Rivers. Avalanches pose hazards to use of the lower Slate Creek route in the winter and spring.

Another overland route starts at Mentasta Village and covers about 50 mi to the head of Slate Creek. This route traverses up the Slana River, then across the Chistochina headwaters, and up the Chisna River to the Slate Creek Valley. Deep snow accumulation up to 20 ft or more along the higher reaches can present difficulty to travel along this route.

Finally, another trail provides winter access to the area from Fish Creek, about 26 mi to the southwest, on the Richardson Highway. With construction of grade crossings and switch backs, it is reported that all-weather access to the property could follow this route (1).

The entire study area is within a block of Federal land that has been selected by the State of Alaska, according to the State's entitlement as provided by the Alaska Statehood Act (Public Law 85-508). The selection was tentatively approved in October, 1987, but no patent has been conveyed. There are over 200 active mining claims in the area, including 37 patented Federal placer claims, 57 unpatented Federal placer claims, and over 100 State mining claims.

HISTORY AND PRODUCTION

Gold was discovered at the confluence of the Chisna and Chistochina Rivers by J.A. Hazelet in 1899 (21). Gravels in the lower Chisna River Valley were very limited in extent; therefore, Mr. Hazelet and other prospectors moved into the Slate Creek and upper Chisna River Valleys. In 1900, gold was discovered on Ruby Gulch by Mr. Hazelet and on Slate Creek and Miller Gulch by Messrs. Coles, Jacobson, Kraemer, and Levell. There has been no recorded lode mineral production in the district.

Total placer production for the district is estimated to be greater than 178,000 troy ounces of gold, 17,000 troy ounces of silver, and 83 troy ounces of platinum, for a total value of about $17,000,000 at the time of sale. Annual production figures for the district, through 1988, are listed in table 1. The platinum production figures reflect only recorded platinum sales and are probably incomplete. Because PGM were not always separated from gold concentrates at the minesite, complete records were not always maintained or preserved, and PGM were sometimes claimed by the U.S. Mint as seigniorage during refining of gold, complete and accurate records for individual mines or districts are not available. Platinum-iron alloy and osmiridium have been recognized in placer concentrates from the Slate Creek area since shortly after gold was first produced in the district. Chapin (7) estimates that "platinum" makes up a little more than 1 pct of the precious metal concentrate recovered during mining. Production records do not, however, confirm that estimate. PGM are recognized in concentrates from Big Four Gulch, Miller Gulch, Slate Creek, and Ruby Gulch. Placer deposits in the upper Chistochina Mining District are also noted for the presence of abundant cinnabar and native copper.

Table 1 - Gold, silver, and platinum production from the Chistochina Mining District

Year	Gold (oz)	Silver (oz)	Platinum (oz)	Number of Mines	Employees	Value
1900	1,209	108	NA	3	12	$25,000
1901	5,563	445	NA	10	75	115,000
1902	10,885	1,142	NA	30	150	225,000
1903	10,885	925	NA	30	150	225,000
1904	12,094	1,088	NA	45	230	250,000
1905	14,029	1,332	NA	50	250	290,000
1906	7,256	812	NA	NA	NA	150,000
1907	1,935	232	NA	NA	NA	40,000
1908	3,870	274	NA	NA	NA	80,000
1909	2,418	205	NA	24	100	50,000
1910	2,902	255	NA	NA	NA	60,000
1911	3,628	399	NA	NA	NA	75,000
1912	3,870	426	NA	NA	NA	80,000
1913	3,870	329	NA	10	40	80,000
1914	2,660	212	NA	NA	NA	55,000
1915	2,902	240	NA	NA	NA	60,000
1916	7,256	800	NA	NA	NA	150,000
1917	4,837	410	NA	NA	NA	100,000
1918	4,837	377	NA	NA	NA	100,000
1919	2,902	271	NA	2	22	60,000
1920	3,628	359	20	5	75	75,000
1921	3,773	490	NA	NA	NA	78,000
1922	3,580	340	15	NA	NA	74,000
1923	1,959	500	6	NA	NA	40,500
1924	1,011	100	NA	NA	NA	20,900
1925	1,548	185	NA	NA	NA	32,000
1926	1,209	108	NA	NA	NA	25,000
1927	798	92	NA	NA	NA	16,500
1928	1,349	134	NA	1	1	27,900
1929	677	80	NA	NA	NA	14,000
1930	1,112	106	NA	1	2	23,000
1931	575	49	NA	4	1	11,885
1932	615	52	NA	5	5	12,712
1933	NA	NA	NA	NA	NA	NA
1934	3	NA	NA	1	1	105
1935	149	4	NA	1	10	5,215
1936	769	73	NA	3	15	26,915
1937	255	22	NA	2	7	8,925
1938	650	57	NA	3	25	22,750
1939	700	64	NA	3	27	24,850
1940	300	24	NA	6	12	10,500
1941	565	53	NA	3	15	19,460
1942	176	8	NA	1	3	6,160
1943	8	NA	NA	1	1	280
1944	NA	NA	NA	NA	NA	NA
1945	NA	NA	NA	NA	NA	NA
1946	778	72	NA	3	10	27,230
1947	528	50	NA	2	8	18,480
1948	413	44	NA	2	8	14,445
1949	41	1	NA	2	8	1,435
1950	1,028	91	NA	3	15	35,980
1951	549	50	NA	3	10	19,215
1952	6	1	NA	1	1	210
1953	30	2	NA	3	3	1,050
1954	91	10	NA	4	4	3,185
1955	92	9	NA	3	4	3,220
1956	868	82	NA	1	10	30,380
1957	2,801	323	NA	3	20	98,035

Table 1 - Gold, silver, and platinum production from the Chistochina Mining District (continued)

Year	Gold (oz)	Silver (oz)	Platinum (oz)	Number of Mines	Employees	Value
1958	2,137	266	NA	2	22	74,795
1959	898	72	NA	1	14	31,430
1960	507	38	NA	3	15	17,745
1961	40	3	NA	1	1	1,400
1962	NA	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA	NA
1964	18	2	NA	1	1	630
1965	NA	NA	NA	NA	NA	NA
1966	NA	NA	NA	NA	NA	NA
1967	NA	NA	NA	NA	NA	NA
1968	3	NA	NA	1	1	105
1969	8	NA	NA	1	1	280
1970	NA	NA	NA	NA	NA	NA
1971	NA	NA	NA	NA	NA	NA
1972	NA	NA	NA	NA	NA	NA
1973	500	NA	NA	1	2	20,000
1974	NA	NA	NA	NA	NA	NA
1975	500	NA	NA	1	2	67,500
1976	NA	NA	NA	NA	NA	NA
1977	NA	NA	NA	NA	NA	NA
1978	NA	NA	NA	NA	NA	NA
1979	4,505	360	NA	3	35	1,350,000
1980	4,220	379	NA	3	30	2,743,000
1981	7,500	781	NA	3	30	3,750,000
1982	3,950	323	NA	2	22	1,639,250
1983	4,600	504	NA	3	22	1,924,000
1984	1,260	119	NA	1	15	453,600
1985	4,911	471	NA	1	15	1,596,075
1986	NA	NA	NA	NA	NA	NA
1987	277	25	15	1	6	126,035
1988	650	84	27	1	6	276,250
Total	178,926	17,344	83			17,171,527

- Data compiled and released to the Bureau by T.K. Bundtzen, Geologist, Alaska Division of Geological and Geophysical Surveys (ADGGS), Fairbanks, AK. Production data mainly derived from Smith (39) for years 1900-1930, unpublished mint returns from 1931-1969, and unpublished State of Alaska records from 1979-1988. Records also obtained from Ranchers Exploration and Development Corporation, Alaska Mineral Resources Company, and Chesna Mining Company. Employment estimates from Biennial Reports of Territorial Department of Mines and ADGGS. Value reported in U.S. Dollars at the time of sale.
- NA indicates not available.

From 1900 through 1910, when gold was valued at $20.67 per fine troy ounce and silver was worth about 60 cents per fine troy ounce, more than $1,500,000 in gold and silver (about 73,000 fine troy ounces of gold and 6,800 fine troy ounces of silver) were produced in the Chistochina District (24). Gold from the district was valued at between $18 and $18.72 per raw troy ounce, indicating a fineness range of about 870-910. Based on six gold fineness determinations, Smith (40) reports a range of 857-887 for the Slate Creek area. Prior to 1911, most of the production in the district came from rich shallow gravels on Miller Gulch and the alluvial fan at the mouth of Miller Gulch, on lower Slate Creek (21). The upper Slate Creek gravels were not as rich, and bedrock was as much as 90 ft beneath the surface.

From 1911 to 1942, an additional $1,200,000 was produced from the district (25). In 1934 the gold price was increased from $20.67 to $34.88 per fine troy ounce and the value of silver increased to about 72 cents per fine troy ounce. In 1942, most placer mines were considered non-essential industrial operations and were shut down by Federal order for the duration of the second world war.

Prior to 1942, mining in the district was done primarily by hydraulic-methods, hand-mining, and sluicing. After the war, when mining revived in the district, more modern, gasoline- and diesel-powered heavy equipment gradually replaced the older methods.

Gold production in the district essentially ceased from 1965 to 1979.

In 1972, following deregulation of gold prices, Ranchers Exploration and Development Corporation consolidated all but the Miller Gulch and Big Four Gulch mining claims in the upper Chistochina-Slate Creek area. They conducted an exploration program from 1972 until 1983, and began mining on Slate Creek in 1979 (1). Using heavy equipment, sluice boxes, jigs, and gravity concentration tables, Ranchers produced 19,666 fine troy ounces of gold at an average grade of 0.0177 fine troy ounces per yd^3 from their operation on upper Slate Creek from 1979 through 1983. In 1984, Ranchers produced 1,260 fine troy ounces of gold from their operation on lower Slate Creek. During the 1984 mining season, Ranchers was acquired by Hecla Mining Corporation.

In 1985, Alaska Minerals Resources Company (1) acquired Hecla Mining Corporation's mining rights in the Chistochina placer district and moved the mining operation from lower Slate Creek to Ruby Gulch (1). That operation produced 4,911 fine troy ounces of gold at a grade of 0.0232 fine troy ounces per yd^3. The company conducted no mining operations on Slate Creek or Ruby Gulch in 1986 or 1987. In 1988, Chesna (the original spelling of Chisna) Mining Company, Denver (CO), acquired an option on the Slate Creek-Ruby Gulch property and is currently conducting tests on tailings and unmined ground.

According to Mr. Howard Hayes, present owner of claims on Miller Gulch, since 1973, small-scale mining operations on Miller Gulch have produced about 3,750 troy ounces of gold.

Mr. Hayes also estimates that during small-scale mining operations between 1973 and 1984, he has recovered over 15 troy ounces of PGM from Miller Gulch concentrates.

Mr. George Cochetas received payment for 7 troy ounces of platinum, recovered during 1988 from a 13.6 troy ounce precious metal concentrate that he produced by tabling several tons of black sand left by Ranchers at the upper Slate Creek property. Ranchers had magnetically separated the material from sluice box concentrates during their mining operations. Also in 1988, Mr. Cochetas shipped 12 tons of concentrate that contained 18 to 20 troy ounces per ton gold and 0.25 troy ounces per ton platinum.

PREVIOUS WORK

Since the early 1900's, local miners referred to the Tertiary conglomerate in the district as "round wash", and they believed, as some still do, that the conglomerate is the source of the placer gold in the district (20-22). Mendenhall (20), however, recognized that "gold-bearing creeks in the district are all within an area whose extent coincides with a region of local metamorphism in the Permian shales". Mendenhall concluded that the gold originated in the shales, which have since been assigned to the Jurassic and Cretaceous Periods, and that in its genesis, the gold is related to the local metamorphism. Chapin (7) stated that gold and "platinum" in the district were derived from the round wash, glacial gravels, and recently-deposited stream gravels. Chapin also stated that there were no nearby basic rocks from which the platinum is likely to have been derived. More recently, Moffit (25) recognized mafic dikes in the area, and Cobb (8) concluded that the platinum probably came from ultramafic rocks in the area.

GEOLOGY

Regional and Structural Geologic Setting

The geology of the Slate Creek area is dominated by two structural features. These are the Denali Fault Zone to the north, and the Slate Creek Fault Zone, near the southern border of the mapped area (fig. 2). The Denali Fault Zone is about 1 mi wide and is covered by glacial ice and morainal debris. The Denali Fault Zone separates low-grade, schistose, Paleozoic and Precambrian metamorphic rocks of the Yukon-Tanana Tectonostratigraphic Terrane (12,27,45) to the north, and outside the study area, from Jurassic-Cretaceous argillite and sandstones of the Kahiltna Terrane. Up to 240 mi of right-lateral displacement, mostly during the Cretaceous and Tertiary Periods, has been demonstrated along the Denali Fault Zone by Turner and others (47) and Tempelman-Kluit(45). The Slate Creek Fault Zone is interpreted by Chapin (7) to be a graben, with high angle faults at the northern and southern margins of the valley. The graben is filled with poorly lithified Tertiary conglomerate with associated sandstone and coal seams. On the slopes north of Slate Creek and parallel to the graben, are high-angle, south-dipping, slickensided surfaces in the Tertiary conglomerate and Jurassic-Cretaceous argillite. These are interpreted as normal fault surfaces that are related to the graben structure. On the south side of the Slate Creek Fault Zone, is a thick section of Permian dacite stocks, dikes, sills, and dacitic extrusive rocks (28).

Intrusion of igneous rocks in the area apparently post-dated the formation of the tighter folds, but, some of the igneous dikes are offset by small-scale faults with displacements ranging from less than one foot to tens of feet. Because the Tertiary conglomerate is cut by faults, at least some of these faults occurred during or after the Tertiary Period.

Rock Units

Dacite Stocks, Dikes, and Sills

The oldest rocks in the study area are south of Slate Creek. These are Permian dacite stocks, dikes, sills, and tuffaceous igneous rocks (28). These rocks contain abundant pyrite and they weather to form conspicuous gossans. Dacitic rocks south of the Slate Creek Fault were found to contain no anomalous concentrations of precious metals, and little or no gold has been produced from streams draining these rocks.

Limestone

A fault-bounded block of massive gray limestone of the Permian Eagle Creek Formation (28) underlies the lower end of Quartz Creek. Buff- to orange-weathering, locally pyritic limestone bodies, too small to be mapped were also observed at the heads of Slate Creek, Ruby Gulch, and Quartz Creek. No metallic minerals other than pyrite were observed in the limestone.

Argillite and Sandstone

The predominant lithology north of the Slate Creek Fault Zone is a black, graphitic, slaty argillite with pale green, locally calcareous, sandstone intervals (fig. 3). The sandstone intervals range in thickness from less than an inch to about 1 ft; most are less than 2-3 in. This sequence changes in metamorphic grade and fabric from relatively unmetamorphosed, slaty, carbonaceous argillite, near Slate Creek, to graphitic phyllite in the upper part of the section, near the Chistochina Glacier. Easterly strikes, parallel to the local and regional structural grain are characteristic throughout the section. In the middle to upper end of Miller Gulch, beds become thinner and grain size in the sandstone intervals decreases. Rhythmic bedding and convolute laminations were observed in the argillite from about midway to the upper end of Miller Gulch. Local variations in strike direction are the result of small-scale folds and faults. Bedding surfaces generally dip between 30 and 80 degrees to the north, toward the Denali Fault Zone. Less abundant, steep southerly dips were locally noted, however, and are interpreted as evidence of overturning of beds, by faulting and folding; consequently, structural thickening of the section has occurred.

Throughout the section are abundant fine calcite veinlets and stockworks with less-abundant quartz veins. Calcite veins and fracture fillings are both contemporaneous with and post-date the quartz veins. The argillite is locally rich in very fine-grained pyrite and is cut by clay gouge-filled, small-scale faults, with offsets measuring from several inches to 1- or 2-ft. The orientation of these faults is very erratic and locally they were observed to change from near-vertical to sub-horizontal within several hundred feet. The faults have two primary strike directions, east, and north. As a result of intensive faulting and brittle deformation caused by intrusion of igneous rocks in the area and deformation associated with movement along the nearby Denali Fault Zone, the entire argillite section is highly fractured.

The argillite section was believed by Mendenhall (20,21), Mendenhall and Schrader (22), and Moffit (25) to be part of the Mankommen Formation, variously assigned to the Carboniferous and Permian Periods. More recently however, Nokleberg and others (28) noted similarities among the argillites in the Slate Creek area to fossil-bearing turbidites in the Nabesna Quadrangle, to the east, and interpreted the turbidites in the Slate Creek area to be of Jurassic or Cretaceous age. During the present investigation, a fossil assemblage was collected in the Miller Gulch and upper Slate Creek areas. Included in the assemblage were an ammonite and a pelecypod specimen that was recognized in the field by Arne Bakke[4] as *Buchia*, an important indicator fossil of Jurassic and Cretaceous turbidites in Alaska. The pelecypod specimen was identified by D.L. Jones[5] as Late Jurassic *Buchia concentrica* and the ammonite as probably *Phylloceras*, of indeterminate age (written communication from D.L. Jones[5]).

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Figure 3. - North-dipping slaty argillite with lighter-colored sandstone intervals in lower Miller Gulch.

Minerals identified during examination by petrographic microscope and scanning electron microscope of argillite samples include illite and other clay minerals, carbonaceous material, quartz, calcite, feldspar, and minor amounts of pyrite, magnetite, and barite. Minute gold particles, all less than 10 microns across, were observed in quartz and pyrite in the argillite. Very fine grains of gold were panned from argillite bedrock and argillite talus samples collected marginal to igneous dikes. Care was taken to avoid contamination by placer gold and placer platinum. Prior to panning, the samples were washed, crushed, washed again, and pulverized. In addition to gold, the heavy mineral concentrates produced in this fashion contained abundant very fine-grained pyrite. An osmiridium grain was also recovered in a heavy mineral concentrate panned from washed, crushed, and pulverized argillite talus from a steep slope on lower Miller Gulch (map number 88, fig. 2).

Differentiated Igneous Rocks North of the Slate Creek Fault Zone

Between the Denali Fault Zone and the Slate Creek Valley, differentiated and hydrothermally-altered dikes and sills of ultramafic, mafic, and intermediate rocks intrude the entire argillite section. Cross-cutting relationships observed among the dikes indicate that there were several episodes of igneous activity in the area. Two major rock units, defined as mafic to ultramafic stocks and sills (TKg), and intermediate to mafic hypabyssal dikes (TKd) were distinguished primarily on the basis of intrusive style, morphology, and composition (fig. 2). The plutons comprise mafic to ultramafic stocks and sills ranging from 1,000 to 4,000 ft in maximum horizontal dimension and smaller, intermediate to mafic, hypabyssal dikes, ranging from several inches to 100 ft wide, that occur in parallel sets and swarms with multiple orientations. For the most part, the larger plutons and the smaller dikes contain the same primary minerals. The only exception to this is the presence of potassium feldspar phenocrysts in some of the porphyritic dikes. The sills, stocks, and dikes contain the same alteration minerals. The larger stocks and sills comprise cumulate, coarse-grained, ophitic to subophitic gabbros with minor associated alkali gabbro, dunite, magnetite-peridotite, serpentinite, hornblendite, plagioclase-hornblendite, and diorite. The smaller dikes tend to be much finer-grained than are the rocks in the larger plutons, although hypabyssal porphyritic rocks with aphanitic groundmasses are common in some of the wider dikes. The dikes are mostly altered diorites and andesites, but, they also include altered gabbro, diabase, hornblendite, diorite porphyry, syenodiorite, syenodiorite porphyry, and dacite.

The gabbros and associated ultramafic rocks (TKg) occur in three areas shown in figure 2. One mass, which contains mostly coarse-grained hornblende gabbro, commonly with coarse interstitial magnetite, and cut by numerous plagioclase-hornblendite dikes is exposed between Miller Gulch and the Chistochina River Valley, at the terminus of the Chistochina Glacier. Similar gabbroic rocks, mixed with altered diorite, also crop out in the igneous mass to the north of upper Slate Creek (fig. 4) on the south side of the Chistochina Glacier. Gabbro, with minor associated dunite, pyroxenite, and serpentinite also crops out in an igneous body of unknown extent at the head of Quartz Creek. The argillite at the southern margin of this mass is sheared and the igneous rocks are serpentinized along the intrusive contact. The gabbros and associated rocks in all three bodies are locally intruded by diorite, diorite porphyry, andesite, hornblendite, and diabase dikes. The close spatial relationship of the dikes and gabbro bodies, the presence of lithologies common to both suites, and cross-cutting dikes in the gabbro indicate that the two are genetically related. The dikes intrude the gabbro stocks and sills, are more siliceous, and are probably slightly younger differentiates of a mutual magmatic source.

Figure 4. - North-dipping differentiated mafic and ultramafic sill (TKg) capping ridge and overlying slaty argillite (KJa) at upper Slate Creek. View to the north.

The differentiated igneous rocks in the Slate Creek area, like the argillite country rock, are cut by calcite and less abundant quartz stockworks and veinlets. Very fine-grained sulfide minerals including pyrite, pyrrhotite, and chalcopyrite are commonly present in all igneous lithologies.

The dikes occur in swarms and as isolated dikes throughout the study area. The highest concentration of dikes is in the Miller Gulch area, where multiple structural orientations are observed among the dikes (figs. 2 and 5). The dikes are less abundant outside the Miller Gulch area; east of Miller Gulch, mostly easterly strikes are observed. The dikes are typically from several inches to 2 ft wide, but individual dikes of east-striking, near vertical, andesite, diorite porphyry, and syenodiorite porphyry up to 60 ft thick, are present in Miller Gulch (fig. 6) and upper Slate Creek Valley. Also, a 200-ft-wide, east-striking, diorite dike, which lacks the distinctive feldspar phenocrysts that characterize the diorite porphyry and syenodiorite porphyry in the Miller Gulch area, crops out at the mouth of Ruby Gulch. A similar, 100-ft-wide dike with several narrower, parallel dikes crops out at the head of Ruby Gulch. In the Miller Gulch area, narrow dikes less than a few inches thick and the margins of thicker dikes are, in many places, almost completely replaced by silica, calcite, and fine-grained sulfide minerals. In general, sulfide mineral content is greatest in the more extensively silicified dikes. Alteration has not only affected dike margins, but has indurated and increased the sulfide mineral content of the adjacent argillite. In addition to sulfide minerals, hematite is pervasive in the argillite where it is intruded by the igneous rocks.

In thin section and polished thin section, using both standard reflected and transmitted light techniques, the dikes, gabbros, and ultramafic rocks exhibit many common features. All of the igneous rocks have been affected by hydrothermal alteration to the extent that pseudomorphic feldspar, both interstitial and phenocrysts, are completely replaced by fine-grained aggregates of quartz, white mica, carbonate, epidote, and clay minerals. Based on the habit of the feldspar phenocrysts and the presence of relict concentric zoning and twinning in various phenocrysts,

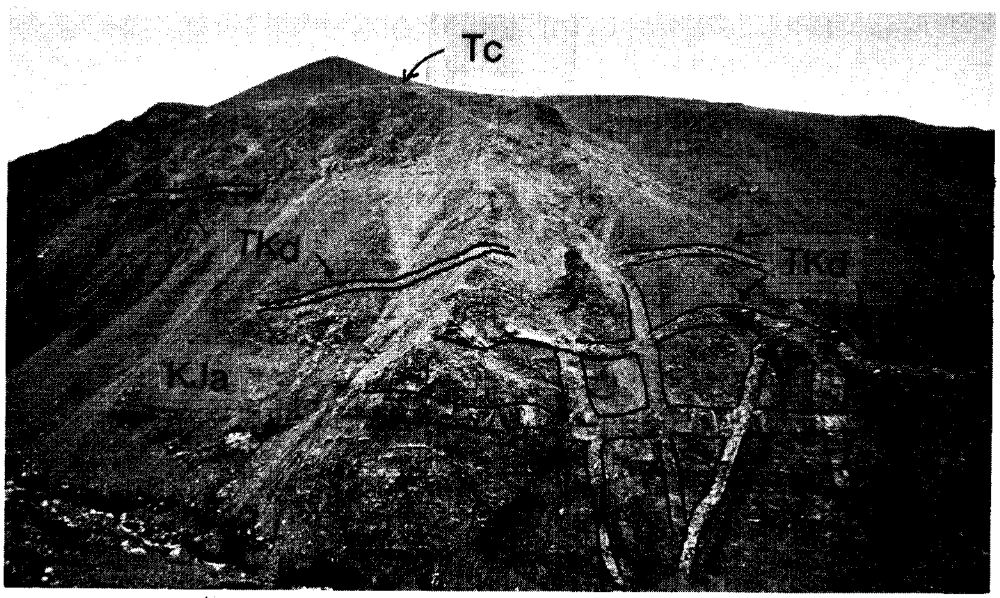


Figure 5. - Dike swarm (TKd) cutting Jurassic-Cretaceous turbidites (KJa) in Miller Gulch. Tertiary conglomerate (Tc) mantles the erosional scarp beneath the ridge crest in upper portion of the photograph. View to the east. The larger, vertical dikes in lower right are diorite porphyry with quartz-calcite veinlets and disseminated pyrite (map number 69).

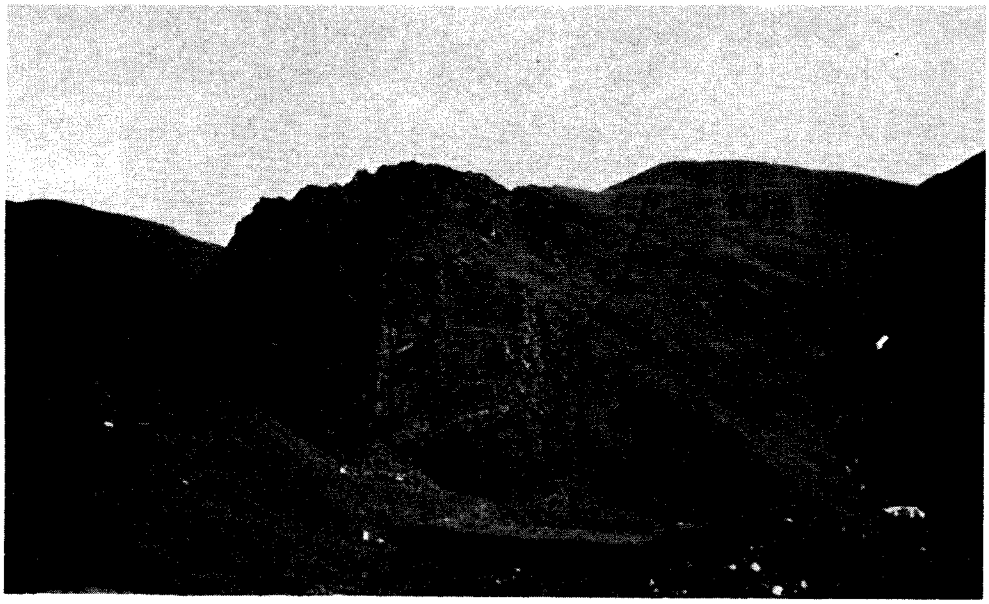
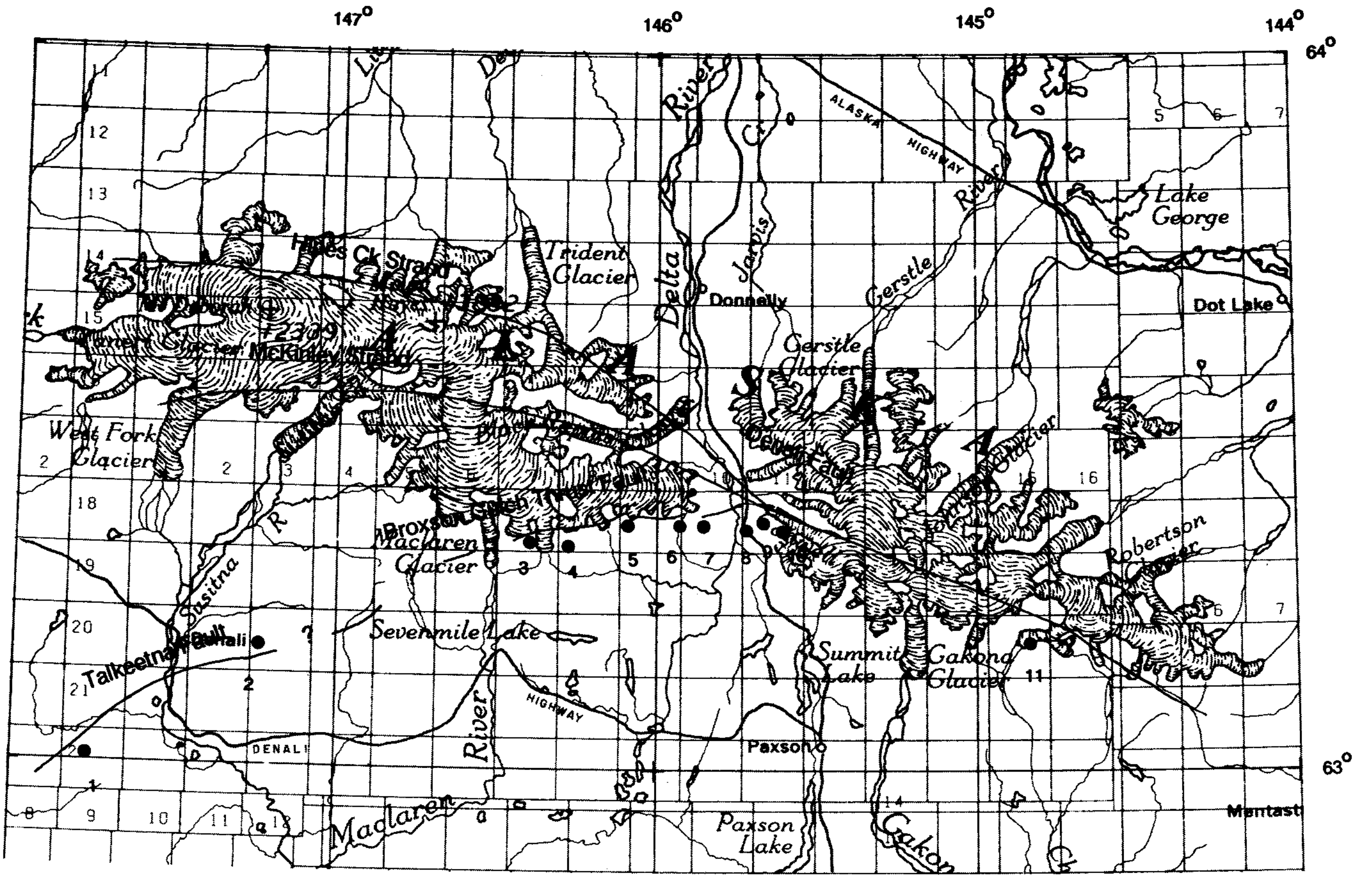


Figure 6. - 60-ft-wide diorite porphyry and syenodiorite porphyry dike at Miller Gulch. Map number 74, view to the east.

both plagioclase and potassium feldspar were originally present in the dikes. No feldspar phenocrysts were observed in specimens from the larger plutons, where feldspar is interstitial and anhedral. In addition to altered feldspar, major and minor minerals present in various amounts and common to all the igneous rocks are hornblende, orthopyroxene, clinopyroxene, and olivine. Poikilitic hornblende and orthopyroxene typically contain equant inclusions of clinopyroxene and olivine. Common accessory minerals include abundant very fine-grained apatite and secondary, microscopic amphibole overgrowths. Mafic minerals are variably altered to very fine-grained, complexly intergrown chlorite, serpentine, talc, sphene, and amphibole. In some of the more altered ultramafic rocks and diabase dikes, pyroxene and olivine are replaced by twinned calcite. Accessory and minor opaque minerals include pyrite, pyrrhotite, cinnabar, and magnetite. Some of the magnetite contains exolved ilmenite.

The differentiated igneous rocks in the Slate Creek area are within a 120-mi-long belt of intrusive mafic and ultramafic rocks, along the Denali, Broxson Gulch, and Talkeetna Fault Systems, in the eastern and central Alaska Range (2,3,16,24,26,28,32-35,41). Within this belt (fig. 7), numerous placer and lode PGM occurrences are known to exist (2,8,11). At many of these sites, differentiated igneous rocks include various combinations of serpentinite, dunite, peridotite, plagioclase-peridotite, gabbroic rocks, diabase, diorite, and quartz diorite. Where present, the dunites in this belt contain a remarkable paucity of chromite. Also at many of these sites, is a very distinctive rock which ranges in composition from a noritic gabbro to a troctolitic gabbro. Plagioclase generally makes up less than 20 pct of this rock which, in most cases, contains accessory to minor amounts of a very distinctive, deep reddish-colored biotite. Nokleberg and others (28) suggest that the ultramafic and related rocks in the Mt. Hayes Quadrangle represent oceanic basement or lithosphere accreted to the North American continent. Intrusive contacts in the Slate Creek area and at many other locations along this belt, however, indicate that these rocks were intruded as partially molten magma into the crust, possibly during accretion of the Kahiltna Terrane and deformation along the Denali Fault (18).



PGM-bearing mafic and ultramafic rocks

1. Butte Creek
2. Eldorado Creek
3. Eureka Glacier
4. Landslide Creek
5. Broxson Gulch
6. Rainy Creek
7. Ann Creek
8. Miller Creek
9. Glacier Lake
10. Canwell Glacier
11. Slate Creek

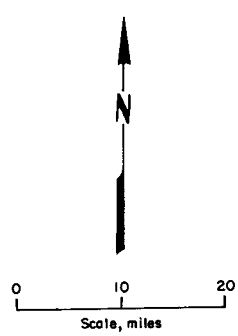


Figure 7. - Map showing the locations of PGM-bearing mafic and ultramafic rocks and major faults in the east-central Alaska Range.

No isotopic ages are available for the igneous rocks in the Slate Creek area. Potassium-argon ages of 92 million years and 97 million years for hornblende in hornblende diorite and hornblende gabbro from the Miller Creek area, 35 miles to the west of Slate Creek, are reported (T.K. Bundtzen, pers. comm., 1989). These data indicate that mafic and associated ultramafic intrusive rocks, elsewhere in the 120-mi-long belt, may be of Late Cretaceous age.

Similar rocks at numerous locations along the south side of the Denali Fault Zone and along the Broxson Gulch Thrust Fault, in the western Mt. Hayes and southeastern Healy Quadrangles, have been questionably assigned to the Late Triassic Period by Richter and Jones (33) and Nokleberg and others (28) who speculate that the intrusive rocks are comagmatic with the Nikolai Greenstone, which has variously been assigned a Triassic age (10,33). Smith and others (41) note that basaltic rocks of the Amphitheatre Group, also in the western Mount Hayes and southeastern Healy Quadrangles, which have been correlated with the Nikolai Greenstone, have been assigned a Late Triassic (Late Carnian or Norian age) by Csejtey and others (10) versus a pre-Late Carnian age for the Nikolai Greenstone on the basis of faunal evidence. The Triassic ages are not supported by radiometric data. Smith and others (41) also note that the Amphitheatre Group rocks in the Healy Quadrangle are intruded by upper Triassic stocks, dikes, and sills of mafic and intermediate rocks.

Because the differentiated igneous rocks in the Slate Creek area intrude upper Jurassic through Cretaceous turbidites, and are overlain by Tertiary conglomerates, the igneous rocks must be provisionally assigned to the Cretaceous or Tertiary (?) periods.

Major oxide analyses (table 2) show that the Cretaceous-Tertiary (?) igneous rocks in the upper Chistochina Mining District range from subalkaline (tholeiitic) to alkaline in composition. Hence, chemical classification of these rocks, according to procedures outlined by Streckeisen and Le Maitre (43), reflects the presence of either normative quartz or normative olivine and feldspathoid. Petrographic examination reveals that primary olivine is present in many of the igneous rocks. Most of the quartz in the rocks is, conversely, clearly secondary in origin and probably crystallized during hydrothermal alteration. The presence of secondary quartz could also explain the subalkaline character of some of the rocks as determined by major oxide chemical data. The most common explanations for the coexistence of alkaline and subalkaline igneous rocks include mixing of magmas or crustal contamination of alkaline or basaltic magmas (5,17,50). Others (30,48,49) have shown that fractional crystallization in the presence of water and carbon dioxide can also explain the coexistence of alkaline and subalkaline igneous rocks. The presence of amphibole and pervasive silica-carbonate alteration of the differentiated igneous rocks indicate that this may have been the case in the Slate Creek area.

Comparison of the major oxide chemistry (table 2) of the dikes to the major oxide chemistry of the larger sills shows that the two groups of rocks have similar compositions for most components, and that the two groups of rocks are magmatically related. Relative to the larger plutons, the dikes are enriched in silica, soda, and potash, and are depleted in ferric iron and titanium dioxide. The ranges of the other analyzed compounds, notably alumina and magnesia, for the two groups of rocks are similar. The relative abundance of silica, soda, and potash in the dikes are probably the result of differentiation by fractional crystallization and, in part, hydrothermal alteration. The depletion of ferric iron and titanium dioxide in the dikes is also probably a result of fractional crystallization.

Major oxide data and Thornton-Tuttle (46) differentiation indexes (DI) for sills and dikes in the Slate Creek area are plotted in figure 8. The data show continuity between the two rock suites and graphically illustrate the chemical differentiation trends among the various major oxides.

TABLE 2. - Major oxide chemistry and chemical classification of igneous rocks from the upper Chistochina Mining District

Map no.	Sample no.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Chemical Classification[1] and pluton type
28	AK23693	44.81	18.21	7.90	5.00	5.63	10.01	2.70	1.50	1.10	0.45	0.24	gabbro sill
29	AK23694	44.72	18.56	7.25	4.80	6.01	8.69	2.70	1.00	1.00	0.40	0.23	gabbro sill
30	AK24290	39.91	11.76	8.90	6.20	9.42	11.95	1.30	0.70	1.29	0.06	0.19	gabbro sill
33	AK24291	56.30	17.89	5.00	1.90	3.39	5.73	4.90	2.90	0.51	0.25	0.10	syenodiorite dike
34	AK24374	41.96	13.96	7.80	6.70	11.50	11.86	1.80	1.20	1.64	0.04	0.18	alkali gabbro sill
42	AK23690	51.77	19.86	3.65	3.70	3.21	6.48	4.00	3.90	0.69	0.40	0.10	syenodiorite dike
55	AK24389	41.23	8.13	14.80	6.20	8.84	14.47	1.20	0.60	1.33	0.08	0.29	ultramafic sill
56	AK24390	41.38	14.74	8.50	6.70	8.33	11.19	1.80	0.90	1.26	0.50	0.25	gabbro sill
62	AK24358	47.30	13.44	6.10	7.10	7.19	10.16	1.90	1.20	1.12	0.39	0.22	gabbro sill
65	AK24357	57.37	16.91	4.75	3.40	4.74	4.14	2.60	2.50	1.13	0.19	0.11	dacite dike
66	AK24356	52.39	17.77	4.80	5.20	4.67	7.15	3.30	3.30	0.98	0.38	0.18	diorite dike
74	AK23684	52.13	17.93	2.45	5.70	4.34	6.40	3.20	3.30	0.83	0.41	0.17	diorite dike
74	AK23688	49.58	13.00	3.90	6.80	8.54	7.39	1.40	2.30	0.93	0.28	0.21	gabbro dike
74	AK23689	52.37	18.00	1.80	5.20	4.60	5.73	3.20	3.50	0.83	0.43	0.17	diorite dike
106	AK24384	53.32	13.90	2.00	5.20	10.95	4.73	1.90	2.00	0.53	0.24	0.15	gabbro dike
108	AK23685	52.72	17.87	3.55	5.10	4.69	6.86	3.70	3.30	0.89	0.44	0.18	syenodiorite dike
109	AK23686	47.09	18.07	2.50	6.80	3.56	7.81	3.60	2.20	0.87	0.37	0.16	diorite dike
112	AK24382	47.82	16.27	4.65	6.40	4.67	10.77	2.10	1.80	0.81	0.30	0.19	gabbro dike

[1] Rocks classified according to normative quartz-alkali feldspar-plagioclase-feldspathoid mineral composition as described by Streckeisen and Le Maitre (43). Values in weight percent.

Granitic Rocks

A small stock (TKq, fig. 2), measuring about 400 by 1,000 ft in area, and an east-striking dike of propylitically-altered granitic rocks crop out on upper Slate Creek. The stock is mapped as gabbro by earlier workers (28). No gabbro was observed at this location during the present investigation. Based on field identifications, rock types in the small stock and dike include monzonite, quartz monzonite, diorite, and quartz diorite. No metallic minerals were observed in these rocks. The age of these rocks is unknown, but, because the rocks intrude upper Jurassic-Cretaceous argillite, they are also assigned a Cretaceous-Tertiary (?) age.

Tertiary Conglomerate

Poorly lithified Tertiary conglomerate crops out in discontinuous patches at numerous locations in the valleys and south-facing ridges of Slate Creek and Chisna River Valleys (Tc, fig. 2). These terrestrial sedimentary rocks were correlated by Mendenhall (21) with the Eocene Gakona Formation. Locally associated with this conglomerate, in the Slate Creek and Chisna River Valleys, are fossiliferous sandstone and coal beds. The conglomerate contains very well-rounded boulders of greenstone, and rocks of granitic to dioritic composition that average about 1 ft in diameter. Smaller, flat pebbles of quartz-mica schist, hematite-stained quartz cobbles and pebbles, and sand make up the matrix of the conglomerate. On the north side of the valleys, decomposed, boulder-

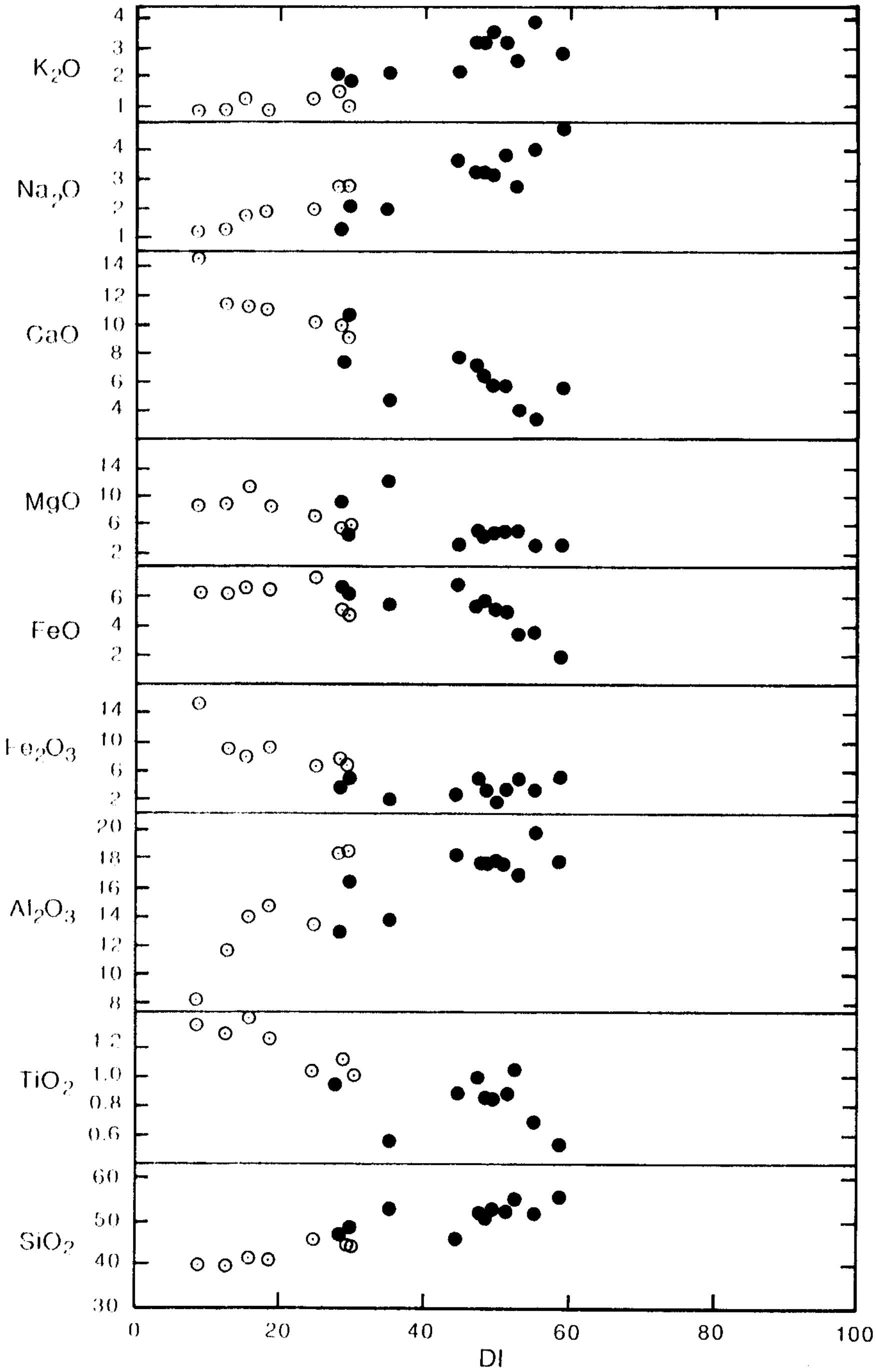


Figure 8. - Major oxides versus Thornton-Tuttle differentiation index. Open circles represent sills and solid circles represent dikes.

rich rubble, formed by the weathering of the conglomerate, covers some of the south-trending ridges up to 5,500-ft elevations. Concentrations of this rubble occur on erosional scarps at several hundred foot vertical intervals on the slopes north of Slate Creek. The presence of hematite-stained slickensides in the conglomerate rubble are the result of steep, south-dipping faults that parallel the Slate Creek graben. The presence of these gravels at progressively higher elevations to the north indicate that normal faulting postdates or occurred contemporaneously with deposition of the conglomerate.

Mendenhall (20,21), Mendenhall and Schrader (22), and Moffit (24-26) reported competent beds of this conglomerate with southerly dips exposed in placer mine workings, but, such are not presently exposed. The sandstone and coal beds have been down-thrown in the Slate Creek graben and are believed to represent higher levels of the Tertiary sedimentary rock sequence than are the more deeply-eroded conglomerate on the ridges to the north (7).

Mendenhall (20,21), Mendenhall and Schrader (22), and Moffit (24-26) also recognized conglomerate on the south side of the Slate Creek Valley. They reported that the conglomerate did not contain clasts of the underlying dacitic bedrock, but, rather an abundance of greenstone, diorite, and schist, indicating that the conglomerate had its provenance to the north of Slate Creek and probably to the north of the Denali Fault Zone, where the Yukon-Tanana Terrane comprises schist, greenstone, and granitic rocks (12, 27, 45).

During this study, several coarse and numerous fine, very bright gold grains were panned from screened decomposed Tertiary conglomerate collected at several sites in the study area (e.g. map numbers 36 and 119, fig. 2, and several sites in the upper Slate Creek Valley).

GEOCHEMISTRY AND METALLURGY

Analytical results for rock samples collected during the present investigation are listed in table 3. Rock chip samples were collected for geochemical analyses at the numbered map locations shown on figure 2. Except for the granitic rocks on upper Slate Creek, all lithologies were sampled and analyzed. The collection and analysis of samples was concentrated on rocks that contained sulfide minerals. Aside from rocks selected for major oxide analysis, some apparently unmineralized rocks were also sampled and analyzed.

Summary statistics for igneous rock samples and Jurassic-Cretaceous argillite samples collected north of the Slate Creek Valley are listed, respectively, in tables 4 and 5. Because the igneous rocks in the study area are extremely differentiated, their chemistry is compared to average igneous rocks (table 4). The data show that, compared to average igneous rocks, the Cretaceous-Tertiary (?) igneous rocks are enriched in all the elements listed in table 4 except for nickel and palladium. Most striking among the enriched elements are arsenic, gold, mercury, platinum, and silver. Based on comparison of the observed means to the quoted averages for igneous rocks (36), the apparent enrichment in cobalt, chromium, and zinc is less salient.[6]

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[6] If the mean gold composition for the igneous rocks in the Slate Creek area were compared to the average gold content of mafic rocks, as reported by Govett (14), the calculated enrichment factor in table 4 would be reduced to 4. Similarly, if compared to the average value reported by Petrovskaya (29) for mafic rocks, the enrichment factor would be 1.5.

Table 3 - Analytical data for rock samples from the Slate Creek area, northern Chistochina Mining District

Map Number	Sample Number	Ag ppm	As ppm	Au ppb	Co ppm	Cr ppm	Cu ppm	Hg ppb	Mo ppm	Ni ppm	Pb ppm	Pd ppb	Pt ppb	Sb ppm	Zn ppm	Descriptions
1	AK26961	<0.5	<5	<5	--	--	10	70	4	--	--	2	<15	<5	--	Pyrite-rich, graphitic argillite gossan (KJa).
2	AK26269	<0.5	<5	<5	--	--	134	40	<1	--	--	8	<15	11	--	Fine-grained silicified diorite with pyrite (TKg).
3	AK26270	0.7	9	<5	--	--	84	60	<1	--	--	20	<15	18	--	Fine-grained gabbro with anorthositic segregation (TKg).
4	AK26959	0.8	15	5	--	--	40	45	<1	--	--	20	30	<5	--	Anorthositic gabbro (TKg).
5	AK26957	<0.5	<5	<5	--	--	30	55	<1	--	--	6	<15	<5	--	Cumulate gabbro (TKg).
6	AK26958	<0.5	5	9	--	--	18	40	<1	--	--	<2	15	<5	--	Anorthosite (TKg).
7	AK26268	<0.5	<5	<5	--	--	127	100	<1	--	--	6	<15	11	--	Fine-grained silicified diorite with pyrite (TKg).
8	AK26962	<0.5	<5	<5	--	--	44	90	2	--	--	15	<15	<5	--	Fine-grained pyritic altered gabbro (TKg).
9	AK26277	<0.5	27	<5	--	--	44	50	<1	--	--	6	35	18	--	Medium-grained anorthositic gabbro with abundant pyrite (TKg).
10	AK26288	0.5	<5	10	--	--	13	330	<1	--	--	<2	15	<5	--	Quartz-hematite vein in altered diorite (TKg).
11	AK26289	0.7	<5	13	--	--	62	130	<1	--	--	20	15	<5	--	Pyritic quartz vein in diorite (TKg).
12	AK26287	<0.5	12	17	--	--	330	390	7	--	--	10	<15	<5	--	Malachite-stained quartz and calcite from fracture in diorite (TKg).
13	AK26286	<0.5	<5	5	--	--	217	80	<1	--	--	15	15	<5	--	Malachite-stained diorite (TKg).
14	AK26285	<0.5	<5	7	--	--	363	180	<1	--	--	8	<15	15	--	Pyritic altered diorite (TKg).
15	AK26284	1.0	<5	15	--	--	139	650	<1	--	--	4	<15	<5	--	Sheared and altered diorite (TKg).
16	AK26274	1.7	7	10	--	--	28	1050	1	--	--	4	<15	13	--	Silica-carbonate-altered diorite dike in autoclastic altered gabbro (TKg).
17	AK26276	<0.5	<5	<5	--	--	105	140	<1	--	--	15	15	20	--	Chloritic sheared diorite with calcite veinlets bounded by hematite (TKg).
18	AK26275	<0.5	<5	<5	--		90	350	<1	--	--	2	<15	7	--	Pyrite-rich silicified diorite (TKg).
19	AK26290	<0.5	6	<5	--	--	455	45	2	--	--	2	<15	<5	--	Pyritic quartz vein (TKg).
19	AK26291	1.8	12	12	--	--	53	215	2	--	--	2	20	7	--	Pyrite-chalcopyrite-quartz breccia from lateral moraine.

See notes at end of table

Table 3 - Analytical data for rock samples from the Slate Creek area, northern Chistochina Mining District (continued)

Map Number	Sample Number	Ag ppm	As ppm	Au ppb	Co ppm	Cr ppm	Cu ppm	Hg ppb	Mo ppm	Ni ppm	Pb ppm	Pd ppb	Pt ppb	Sb ppm	Zn ppm	Descriptions
20	AK26273	<0.5	15	<5	--	--	60	45	1	--	--	6	<15	14	--	Silica-carbonate-altered pyritic diorite (TKg).
21	AK26272	0.8	22	5	--	--	88	35	<1	--	--	6	<15	9	--	Pyritic and graphitic, phyllitic argillite (KJa).
22	AK26267	<0.5	<5	<5	--	--	109	40	<1	--	--	15	15	12	--	Serpentinite with calcite and hematite (TKg).
22	AK26271	0.7	<5	7	--	--	117	25	<1	--	--	8	<15	24	--	Very fine-grained, silicified, and carbonate-altered diorite with fine calcite veinlets (TKg).
23	AK26281	<0.5	<5	6	--	--	70	30	3	--	--	6	<15	<5	--	Pyritic, carbonate-altered diorite (TKg).
23	AK26282	0.7	10	8	--	--	96	45	<1	--	--	6	<15	12	--	Argillite cut by quartz and calcite veins, adjacent to diorite dike (KJa).
23	AK26283	<0.5	<5	7	--	--	60	60	<1	--	--	<2	<15	22	--	Argillite cut by quartz and calcite veins, adjacent to diorite dike (KJa).
24	AK26312	<0.5	15	56	--	--	58	125	<1	--	--	<2	<15	<5	--	Red-stained, calcite-rich, fault gouge in argillite (KJa).
25	AK26314	1.1	69	17	--	--	2410	340	<1	--	--	10	25	8	--	Pyritic, altered and sheared diorite from contact with argillite (TKg).
26	AK26313	<0.5	12	13	--	--	119	55	<1	--	--	25	<15	<5	--	Coarse-grained pyroxenite with pyrite and chalcopyrite (TKg).
27	AK26315	2.0	12	10	--	--	1787	70	3	--	--	<2	<15	11	--	Pyritic, quartz-biotite schist from moraine.
28	AK23693	--	--	--	--	--	--	--	--	--		15	<50	--	--	Hornblende gabbro (TKg).
29	AK23694	--	--	--	--	--	--	--	--	--		15	<50	--	--	Hornblende gabbro (TKg).
30	AK24290	--	--	--	--	--	--	--	--	--		5	<50	--	--	Pegmatitic plagioclase hornblendite (TKg).
31	AK21802	1.8	--	<7	<2	--	120	--	--	220	<80	--	--	--	800	limonite-coated pyritic pyroclastic float.
32	AK24372	--	--	<9	--	--	--	--	--	--	--	5	70	--	--	Hornblende gabbro (TKg).
33	AK24291	--	--	--	--	--	--	--	--	--	--	<5	<50	--	--	Fine-grained diorite in gabbro (TKg).
34	AK24374	--	--	--	--	--	--	--	--	--	--	<5	<50	--	--	Pegmatitic hornblendite (TKg).
35	AK24375	<5	<30	<9	39	230	8	--	--	76	<10	20	<50	100	--	Hornblendite (TKg).

see notes at end of table

Table 3 - Analytical data for rock samples from the Slate Creek area, northern Chistochina Mining District (continued)

Map Number	Sample Number	Ag ppm	As ppm	Au ppb	Co ppm	Cr ppm	Cu ppm	Hg ppb	Mo ppm	Ni ppm	Pb ppm	Pd ppb	Pt ppb	Sb ppm	Zn ppm	Descriptions
37	AK23692	9	60	45	40	120	970	12000	--	49	<10	20	90	--	140	Silicified and carbonate-altered dike with abundant pyrite and pyrrhotite (TKd).
38	AK23691	<5	97	<5	15	28	250	0.017[1]	--	7	--	15	55	--	55	Silicified and carbonate-altered hornblende diabase dike (TKd).
39	AK24206	--	--	15	--	--	--	--	--	--	--	5	<50	--	--	Silicified and carbonate-altered diorite dike (TKd).
39	AK24207	<0.1	5	45	15	--	35	55	--	--	2	20	<15	--	175	Silicified and carbonate-altered diorite dike (TKd).
40	AK25371	--	--	<5	--	--	--	--	--	--	--	<5	<50	--	--	Silicified argillite (KJa).
40	AK25372	--	--	<5	--	--	--	--	--	--	--	<5	<50	--	--	Silicified argillite (KJa).
41	AK21994	<0.3	<7	--	--	--	--	--	--	--	--	<10	<10	--	--	Pyritic andesite dike (TKd).
42	AK23690	--	--	--	--	--	--	--	--	--	--	15	<50	--	--	Hornblende diorite with pyrite (TKd).
43	AK24366	<5	120	<5	12	81	48	--	--	23	<10	<5	60	--	87	Hornblende diorite (TKd).
44	AK24367	<5	72	<5	34	54	15	--	--	46	<10	<5	<50	--	100	Plagioclase hornblendite (TKd).
44	AK24368	<5	<2	<5	<1	130	32	12	--	30	<10	10	<50	--	930	Carbonate-altered hornblendite (TKd).
45	AK24361	<5	95	<9	17	81	200	--	--	30	<10	<5	<50	--	110	Fine-grained diorite segregation (TKg).
46	AK24362	<5	<2	<5	20	99	190	7000	--	32	<10	<5	<50	--	120	Andesite dike with pyrite, pyrrhotite, and chalcopyrite (TKd).
47	AK24365	<5	<2	<5	24	150	55	12000	--	67	<10	<5	<50	--	140	Argillite (KJa).
49	AK23678	<5	55	<5	38	360	320	--	--	99	<10	20	<50	--	120	Plagioclase hornblendite with pyrite, pyrrhotite, chalcopyrite, and calcite (TKd).
50	AK21800	0.5	--	<7	94	--	830	--	--	170	<80	<10	<10	--	170	Carbonate-altered, silicified and limonite-coated diabase dike (TKd).
50	AK21972	<0.3	--	<7	56	--	540	--	--	120	<80	<10	<10	--	180	hornblende gabbro with pyrite (TKg).
50	AK24265	<0.5	<100	<5	100	300	925	--	--	100	<10	40	70	--	200	Hornblendite with pyrrhotite and chalcopyrite (TKg).
53	AK24360	<5	100	<9	15	49	110	--	--	22	<10	<5	<50	--	110	Fine-grained diorite (TKg).
54	AK24391	<5	89	<9	23	87	340	--	--	33	<10	15	60	--	100	Malachite-stained, pyritic gabbro (TKg).
55	AK24389	--	--	--	--	--	--	--	--	--	--	70	<50	--	--	Hornblende-olivine pyroxenite with magnetite (TKg).

See notes at end of table

Table 3 - Analytical data for rock samples from the Slate Creek area, northern Chistochina Mining District (continued)

Map Number	Sample Number	Ag ppm	As ppm	Au ppb	Co ppm	Cr ppm	Cu ppm	Hg ppb	Mo ppm	Ni ppm	Pb ppm	Pd ppb	Pt ppb	Sb ppm	Zn ppm	Descriptions
56	AK24390	--	--	--	--	--	--	--	--	--	--	25	<50	--	--	Ophitic hornblende gabbro (TKg).
57	AK17708	--	--	--	--	--	--	--	--	--	--	29	<10	--	--	Hornblende gabbro with pyrite, pyrrhotite, and chalcopyrite (TKg).
57	AK24392	<5	<100	<5	30	150	203	--	--	<5	<10	20	55	--	<200	Ophitic hornblende gabbro with pyrite and pyrrhotite (TKg).
58	AK24479	0.1	3	<5	16	--	220	600	--	--	<2	15	<15	--	32	Pyrite-rich hornblende diorite (TKd).
59	AK24388	<5	97	<9	26	89	120	--	--	30	<10	15	<50	--	110	Hornblende dacite with pyrrhotite and chalcopyrite (TKd).
60	AK24387	<5	98	<9	20	64	140	--	--	23	<10	10	55	--	87	Hornblende dacite with pyrrhotite and chalcopyrite (TKd).
61	AK24359	5.3	<2	45	2	130	460	<2000	--	12	<10	<5	50	--	51	Andesite dike (TKd).
62	AK24358	--	--	--	--	--	--	--	--	--	--	15	<50	--	--	Hornblende gabbro with pyrrhotite and chalcopyrite (TKg).
63	AK24376	5.4	110	<9	18	120	97	--	--	51	<10	15	<50	--	120	Dunite segregation in gabbro (TKg).
65	AK24357	<5	<2	<5	14	120	100	<2000	--	37	<10	<5	<50	--	99	Pyritic, silicified, andesite dike (TKd).
66	AK24356	<5	<2	<7	18	99	150	<2000	--	39	<10	5	50	--	99	Diorite porphyry (TKd).
67	AK24355	6	<2	--	19	130	86	3000	--	54	<10	5	<50	--	130	Argillite (KJa).
68	AK26278	0.9	<5	6	--	--	224	1000	4	--	--	10	<15	<5	--	Fine-grained, hornblende-pyroxene gabbro float.
70	AK23687	<5	99	--	38	710	98	--	--	260	<10	10	60	--	160	Andesite dike cut by quartz-calcite veinlets (TKd).
71	AK21991	--	--	--	<2	--	170	--	--	<8	<80	<10	<10	--	110	Pyritic plagioclase hornblendite (TKd).
72	AK23683	<5	43	<5	<1	150	7	--	--	5	<10	5	<50	--	29	Quartz boulder float from Tertiary conglomerate (Tc).
73	AK17909	--	--	--	51	--	280	--	--	110	<80	<10	216	--	140	Plagioclase-hornblendite with pyrite, pyrrhotite, and chalcopyrite (TKd).
74	AK20545	1.6	--	<7	<2	--	3400	--	--	<8	<80	<10	<10	--	77	Malachite-stained argillite (KJa).
74	AK20596	<0.3	--	14	<2	--	160	--	--	<8	<80	65	163	--	120	Diorite porphyry (TKd).

See notes at end of table

Table 3 - Analytical data for rock samples from the Slate Creek area, northern Chistochina Mining District (continued)

Map Number	Sample Number	Ag ppm	As ppm	Au ppb	Co ppm	Cr ppm	Cu ppm	Hg ppb	Mo ppm	Ni ppm	Pb ppm	Pd ppb	Pt ppb	Sb ppm	Zn ppm	Descriptions
74	AK23684	--	--	--	--	--	--	--	--	--	--	5	<50	--	--	Malachite-stained diorite porphyry with epidote veinlets (TKd).
74	AK23688	--	--	--	--	--	--	--	--	--	--	10	<50	--	--	Gabbro dike cutting diorite porphyry (TKd).
74	AK23689	--	--	--	--	--	--	--	--	--	--	<5	<50	--	--	Diorite porphyry (TKd).
74	AK24293	<5	94	<9	32	460	47	--	--	95	<10	10	<50	--	100	Serpentinized olivine pyroxenite in diorite porphyry (TKd).
76	AK25387	0.1	4	20	25	--	130	180	--	--	2	4	<15	--	88	Carbonate-altered diorite with pyrite, pyrrhotite, and chalcopyrite (TKd).
76	AK25388	<0.1	5	30	16	--	90	700	--	--	6	6	15	--	140	Fine-grained diorite dike bounded by clay and calcite fault gouge (TKd).
78	AK24204	<0.1	5	10	28	--	96	75	--	--	11	6	<15	--	74	Porphyritic hornblende diorite (TKd).
79	AK25363	0.2	5	5	20	--	440	400	--	--	7	8	<15	--	120	Malachite-stained argillite (KJa).
81	AK25389	0.5	<2	95	24	--	260	15	--	--	5	6	15	--	108	Fine-grained silicified diorite (TKd).
82	AK25366	0.2	6	5	8	--	138	1250	--	--	34	6	<15	--	40	Pyritic argillite (KJa).
83	AK20595	<0.3	--	532	<2	--	91	--	--	<8	<80	<10	<10	--	78	Diorite porphyry (TKd).
84	AK20544	<0.3	--	<7	<2	--	94	--	--	210	<80	<10	<10	--	96	Diorite porphyry (TKd).
84	AK23682	<5	110	<5	60	30	290	--	--	79	<10	10	<50	--	130	Malachite-stained diabase dike (TKd).
88	AK25381	--	--	25	--	--	--	--	--	--	--	<5	<50	--	--	Argillite talus containing osmiridium grain (KJa).
90	AK25380	--	--	35	--	--	--	--	--	--	--	<5	<50	--	--	Argillite talus (KJa).
92	AK25385	0.2	10	<5	24	--	240	470	--	--	4	10	<15	--	52	Pyritic hornblende diorite (TKd).
93	AK25386	0.3	7	<5	20	--	79	130	--	--	4	4	<15	--	126	Silicified magnetite hornblendite (TKd).
97	AK21999	<0.3	--	<7	51	--	<5	--	--	79	<80	<10	<10	--	150	Plagioclase-magnetite-hornblendite float (TKd).
97	AK22000	--	--	--	64	--	170	--	--	67	<80	<10	<10	--	150	Plagioclase-magnetite-hornblendite float (TKd).
98	AK21974	<0.3	--	<7	<2	--	120	--	--	<8	<80	--	--	--	65	Pyritic dacite tuff (Pd).
98	AK21975	0.5	--	<7	--	--	--	--	--	--	--	--	--	--	--	Plagioclase-hornblendite float with pyrite.
99	AK25908	<0.5	22	5	--	--	220	30	1	--	--	40	85	<5	--	Hornblendite dike in dacitic tuff (Pd).

See notes at end of table

Table 3 - Analytical data for rock samples from the Slate Creek area, northern Chistochina Mining District (continued)

Map Number	Sample Number	Ag ppm	As ppm	Au ppb	Co ppm	Cr ppm	Cu ppm	Hg ppb	Mo ppm	Ni ppm	Pb ppm	Pd ppb	Pt ppb	Sb ppm	Zn ppm	Descriptions
100	AK17756A	<0.3	5	<7	<2	--	<5	--	--	<8	<80	--	--	--	<2	Pyritic tuff (Pd).
100	AK17756B	<0.3	22	<7	31	--	56	--	--	<8	<80	--	--	--	62	Pyritic tuff (Pd)..
102	AK24208	<0.1	5	<5	5	--	36	450	--	--	8	4	<15	--	58	Pyritic argillite cut by quartz and calcite microveinlets (KJa).
102	AK24458	3.9	--	190	--	--	--	5000	--	--	--	<5	<50	--	--	Silicified diorite (TKd).
102	AK25368	0.1	5	25	9	--	56	550	--	--	13	6	<15	--	98	Silicified argillite intruded by 6-in-wide altered diorite dike (TKd).
102	AK25369	<0.1	10	<5	20	--	30	325	--	--	4	6	<15	--	90	North argillite wallrock, adjacent to diorite dike (KJa and TMzd).
102	AK25370	<0.1	5	10	13	--	72	305	--	--	5	6	<15	--	68	South argillite wallrock, adjacent to diorite dike (KJa).
102	AK25373	--	--	5	--	--	--	--	--	--	--	<5	<50	--	--	East end of silicified argillite outcrop (KJa).
102	AK25374	--	--	5	--	--	--	--	--	--	--	<5	<50	--	--	Central portion of silicified argillite outcrop (KJa).
102	AK25375	--	--	10	--	--	--	--	--	--	--	<5	<50	--	--	Replicate of AK25369.
102	AK25376	--	--	10	--	--	--	--	--	--	--	<5	55	--	<200	Replicate of AK25370.
102	AK24447	0.5	<100	65	5	300	20	--	--	5	30	<5	<55	--	<200	Argillite cut by silicified diorite dike (KJa and TMzd).
104	AK24385	<5	110	<9	19	140	83	--	--	52	<10	<5	<50	--	100	Diorite (TKd).
105	AK24386	<5	110	<9	23	120	94	--	--	51	<10	<5	75	--	110	Altered diorite porphyry float with limonite and epidote cavity fillings (TKd).
106	AK24384	--	--	--	--	--	--	--	--	--	--	<5	<50	--	--	Diabase dike with hornblende phenocrysts (TKd).
107	AK24383	<5	120	<9	28	280	53	--	--	64	<10	<5	<50	--	130	Altered diorite porphyry rubble with limonite and epidote cavity fillings (TKd).
108	AK23685	--	--	--	--	--	--	--	--	--	--	<5	<50	--	--	Diorite porphyry (TKd).
108	AK24292	<5	110	--	19	99	300	--	--	46	140	<5	<50	--	170	Diorite porphyry with malachite and pyrite (TKd).

See notes at end of table

Table 3 - Analytical data for rock samples from the Slate Creek area, northern Chistochina Mining District (continued)

Map Number	Sample Number	Ag ppm	As ppm	Au ppb	Co ppm	Cr ppm	Cu ppm	Hg ppb	Mo ppm	Ni ppm	Pb ppm	Pd ppb	Pt ppb	Sb ppm	Zn ppm	Descriptions
109	AK23686	--	--	--	--	--	--	--	--	--	--	<5	60	--	--	Pyritic andesite dike (TKd).
110	AK24380	<5	110	<9	18	110	96	--	--	58	<10	5	<50	--	800	Diorite porphyry (TKd).
111	AK24381	5.5	110	<9	17	91	60	--	--	47	<10	10	65	--	470	Diorite porphyry with chalcopyrite altering to native copper (TKd).
112	AK24382	--	--	--	--	--	--	--	--	--	--	10	<50	--	--	Gabbro rubble in diorite porphyry rubble (TKd).
112	AK24205	<0.1	3	5	20	--	129	415	--	--	2	6	<15	--	46	Porphyritic hornblende diorite (TKd).
113	AK21801	--	--	--	--	--	--	--	--	--	--	<10	<10	--	--	Carbonate-altered, silicified, and limonite-coated diabase dike (TKd).
114	AK23677	5.4	10	21	10	110	91	7.3[1]	--	35	<10	<9	<9	--	85	Cinnabar veinlets in silicified and carbonate-altered diabase dike (TKd).
115	AK24264	--	10	4	9	--	86	0.66[1]	--	35	--	15	70	--	89	Silicified and carbonate-altered diabase dike with cinnabar (TKd).
116	AK24369	<5	86	<9	32	220	150	--	--	58	<10	10	80	--	100	Diabase dike (TKd).
117	AK24370	<5	110	<9	16	97	64	--	--	37	<10	10	60	--	100	Diorite porphyry (TKd).
117	AK25898	<0.5	<5	9	--	--	116	900	1	--	--	15	8	<5	--	Carbonate-altered dike with corroded pyroxene phenocrysts (TKd).
118	AK21776	--	--	--	--	--	--	--	--	--	--	<10	<10	--	--	Malachite-stained magnetite-hornblendite (TKd).
120	AK25900A	<0.5	24	<5	--	--	80	125	<1	--	--	20	30	<5	--	Meta-diorite cobble from Tertiary conglomerate rubble (Tc).
120	AK25900B	<0.5	26	5	--	--	98	3700	3	--	--	<15	4	<5	--	Meta-diorite cobble from Tertiary conglomerate rubble (Tc).
120	AK25900C	<0.5	15	18	--	--	37	155	2	--	--	20	4	<5	--	Meta-diortie cobble from Tertiary conglomerate rubble (Tc).
120	AK25900D	<0.5	18	<5	--	--	40	90	1	--	--	15	<2	<5	--	Meta-diorite cobble from tertiary conglomerate rubble (Tc).
121	AK24371	25	100	<9	34	320	110	--	--	120	<10	15	<50	--	120	Diabase dike (TKd).
122	AK21626	<0.3	--	<7	--	--	--	--	--	--	--	17	<10	--	--	Magnetite-rich, altered peridotite float.

See notes at end of table

Table 3 - Analytical data for rock samples from the Slate Creek area, northern Chistochina Mining District (continued)

Map Number	Sample Number	Ag ppm	As ppm	Au ppb	Co ppm	Cr ppm	Cu ppm	Hg ppb	Mo ppm	Ni ppm	Pb ppm	Pd ppb	Pt ppb	Sb ppm	Zn ppm	Descriptions
123	AK17758	--	--	--	--	--	--	--	--	--	--	<10	<10	--	--	Magnetite-rich, altered peridotite float.
125	AK25826	0.5	14	6	--	--	74	175	30	--	--	6	<15	<5	--	Silicified argillite with abundant pyrite (KJa).
126	AK25827	<0.5	<5	8	--	--	10	135	<1	--	--	8	<15	<5	--	Diorite porphyry (TKd).
128	AK25829	1.3	22	5	--	--	82	225	5	--	--	4	<15	<5	--	Pyritic and graphitic argillite (KJa).
129	AK25830	<0.5	5	11	--	--	100	45	<1	--	--	8	<15	<5	--	Fine-grained mafic dike (TKd).
130	AK24202	--	--	<5	--	--	--	--	--	--	--	<5	<50	--	--	Diorite porphyry dike (TKd).
130	AK26960	2.6	8	<5	--	--	20	40	3	--	--	<2	<15	<5	--	Fine-grained clastic limestone with calcite stockworks and disseminated pyrite (KJa).
131	AK21973	<0.3	10	42	<2	--	110	--	--	<8	<8	--	--	--	130	Carbonate-altered and silicified andesite dike (TKd).
131	AK21995	<0.3	<90	<7	<10	<8	<20	--	--	20	20	<10	<10	--	70	Limonite-stained calcite veins in argillite (KJa).
133	AK24482	<0.1	18	<5	46	--	145	35	--	--	--	15	<15	--	98	Diorite dike (TKd).
134	AK26965	1.5	20	6	--	--	89	45	<1	--	--	6	<15	<5	--	Pyritic argillite (KJa).
135	AK26963	<0.5	<5	<5	--	--	19	215	<1	--	--	2	<15	<5	--	Quartz vein marginal to diorite dike (TKd).
136	AK26964	<0.5	<5	<5	--	--	17	60	2	--	--	<2	<15	<5	--	Pyritic quartz vein in phyllitic argillite (KJa)
137	AK26956	<0.5	<5	5	--	--	42	195	25	--	--	2	<15	<5	--	Pyritic, gray, laminated limestone (KJa).
138	AK26954	<0.5	6	7	--	--	62	60	<1	--	--	6	<15	<5	--	Hematite-rich, chloritic, clay-rich altered diorite (TKg).
139	AK26955	<0.5	7	7	--	--	35	60	<1	--	--	10	15	7	--	Fine-grained, phaneritic gabbro, with twinned calcite veinlets (TKg).
140	AK26280	0.6	6	<5	--	--	12	350	<1	--	--	2	<15	18	--	Silicified and carbonate-altered diorite with pyrite (TKg).
141	AK26966	<0.5	<5	6	--	--	5	45	2	--	--	6	<15	8	--	Buff-orange-colored limestone (KJa).
142	AK26953	<0.5	<5	<5	--	--	122	900	<1	--	--	6	<15	<5	--	Pyritic, hornblende diorite with calcite veinlets (TKg).

See notes at end of table

Table 3 - Analytical data for rock samples from the Slate Creek area, northern Chistochina Mining District (continued)

Map Number	Sample Number	Ag ppm	As ppm	Au ppb	Co ppm	Cr ppm	Cu ppm	Hg ppb	Mo ppm	Ni ppm	Pb ppm	Pd ppb	Pt ppb	Sb ppm	Zn ppm	Descriptions
143	AK26279	<0.5	13	<5	--	--	109	20	<1	--	--	6	<15	5	--	Hematite-coated, altered, cataclastic diorite (TKg).
145	AK25833	0.8	<5	8	--	--	8	65	1	--	--	<2	100	<5	--	Biotite pyroxenite (TKg).
146	AK25832	0.8	<5	7	--	--	8	20	2	--	--	4	230	<5	--	Serpentinite (TKg).
147	AK25831	1.4	<5	<5	--	--	42	70	2	--	--	2	45	<5	--	Argillite (KJa).

-- Not analyzed.

< Less than indicated value.

[1] Hg reported in pct.

- Ag, As, Co, Cr, Cu, Mo, Ni, Pb, Sb, and Zn, analyzed by flame atomic absorption spectrophotometry. Au, Pd, and Pt analyzed by fire assay-atomic absorption spectrophotometry. Hg analyzed by cold vapor atomic absorption spectrophotometry. All analyses by Bondar-Clegg, Inc., Lakewood, CO.

- TKd refers to Cretaceous-Tertiary (?) dikes. Other unit abbreviations are explained in the legend on figure 2.

Table 4 - Geochemistry summary statistics for igneous rocks in the Slate Creek area, northern Chistochina Mining District

	Ag ppm	As ppm	Au ppb	Co ppm	Cr ppm	Cu ppm	Hg ppb	Ni ppm	Pd ppb	Pt ppb	Zn ppm
maximum	25	120	532	100	710	2410	12000	260	70	230	930
minimum	<0.5	<2	<5	<2	28	<5	15	<5	<2	8	32
arithmetic mean	2.4	35.9	16.3	25.9	161.8	181.8	902.5	63.4	11.1	38.7	160.5
standard deviation	3	43	56	21	140	293	2427	58	10	35	177
number of analyses	89	82	91	54	32	91	53	44	114	114	54
average abundance in igneous rocks[1]	0.2	2	1	18	117	70	60	100	20	5	80
average abundance in granite[2]	0.04	1.5	2	3	20	12	30	0.8	3-6	8	50
average abundance in basalt[2]	0.1	2	4	48	200	100	10	150	27	15	100
enrichment ratios[3]	12	17.95	16.3	1.43	1.38	2.60	15.04	0.63	0.56	7.74	2.01

1 From Rose, Hawkes, and Webb (36)
2 Pd and Pt from Crocket (9), and other elements from Krauskopf (19)
3 mean/average abundance in igneous rocks
- In statistical calculations, zero (0) was substituted for values reported as less than a specified detection limit.

Table 5 - Geochemistry summary statistics for Jurassic-Cretaceous argillites in the Slate Creek area, northern Chistochina Mining District

	Ag ppm	As ppm	Au ppb	Co ppm	Cr ppm	Cu ppm	Hg ppb	Ni ppm	Pb ppm	Pd ppb	Pt ppb	Zn ppm
maximum	1.5	22	65	24	300	3400	12000	67	34	8	55	140
minimum	<0.1	<2	<5	<2	130	10	35	5	4	<2	<10	40
arithmetic mean	1.2	8.9	11.1	12.5	193.3	268.4	1187.8	33.5	13.4	5.2	29.8	102.1
standard deviation	1.7	6.9	13.6	7.8	92.9	787.3	2977.2	31.6	10.9	1.7	18.1	47.0
number of analyses	18	16	25	10	3	18	16	4	9	26	26	10
average abundance in shales[1]	0.04	10	3	20	100	50	300	80	20	<30	<30	90
enrichment ratios[2]	12	1.35	11.1	0.62	1.93	4.71	2.97	0.35	0.67	nd	nd	1.28

[1] From Krauskopf (19)

[2] mean/average abundance in shales

nd - not determined

- In statistical calculations, zero (0) was substituted for values reported as less than a specified detection limit.

The enriched background levels of silver, gold, mercury, copper and platinum in the local bedrock indicate that the abundant silver, gold, native mercury, cinnabar, native copper, and platinum in placer concentrates were derived from the local bedrock.

Similar patterns of geochemical enrichment are observed in the Jurassic-Cretaceous argillite and the Cretaceous-Tertiary (?) igneous rocks. The similarity of these enrichment patterns indicates that hydrothermal fluids have similarly affected both major rock types. Because of the lack of more definitive data for shales, enrichment ratios were not calculated for palladium and platinum in the argillites. Comparison of the means for gold and platinum in the two rock types to averages for similar rocks, as listed in tables 4 and 5, shows similar enrichment in gold and platinum in the argillites and igneous rocks. Arsenic and mercury are dramatically more enriched in the igneous rocks than in the argillites. Shales, however, typically contain more arsenic and mercury than do average igneous rocks. The notably high enrichment in these two elements in the igneous rocks is therefore attributed to assimilation from the argillite country rock during intrusion and subsequent extraction of these metals from the argillite during hydrothermal alteration. Various combinations of high gold, copper, mercury, platinum, and silver values were detected in argillite samples collected from areas intruded by silicified and carbonate-altered diorite dikes (map numbers 49, 74, 82, and 102, table 3).

Chemical data for two samples indicate that gold, mercury, PGM, and silver are chemically and mineralogically associated in the Miller Gulch area. A sample from a 1-ft-thick, pyritic, silicified, and carbonate-altered diabase dike, with cinnabar veinlets, (map number 114) contained 7.3 pct Hg, 21 ppb Au, and 5.4 ppm Ag. A similar dike, in the same area, (map number 115) contained 0.66 pct Hg, 15 ppb Pd, and 70 ppb Pt.

Because anomalous gold and PGM values were frequently either erratic or not reproducible, a revised sampling approach was tested. This method consisted of collecting large bedrock and talus samples weighing between 10 and 100 lb, washing the samples and discarding minus-1/4-inch material, and drying the samples prior to crushing and pulverizing. Pulverized splits, weighing between 2 and 10 lb were then carefully panned to concentrate heavy minerals. The analytical data are listed in table 6. Various combinations of anomalous amounts of gold, mercury, palladium, platinum, and silver in igneous rocks and argillite were analyzed and detected in this manner. Gold, mercury, palladium, platinum, and silver were effectively concentrated by panning pulverized igneous rock samples from map locations 40, 50, 52, 57, 78, 78, 80, 81, and 102. Various combinations of gold, mercury, and to a slight degree, palladium and platinum were concentrated by panning pulverized argillite samples from map locations 49, 85, 86, 87, 88, 89, 91, 94, 95, 96, and 102.

Because, in many cases a graphitic froth collected at the surface of the panning vessel, concentrates produced by panning tailings from the pulverized and panned igneous and argillite samples were also analyzed. It was suspected that gold- and PGM-bearing sulfide minerals and fine native precious metal grains might attach to bubbles or electrostatically charged mineral grains in the froth and slimes. Furthermore, a composite sample of tailings and slimes (sample AK25209, table 6), and several composite tailing samples from map numbers 51, 52, 57, and 95 (sample AK26317, table 6) and from map locations 86, 88, and 90 (sample AK25384, table 6) were also panned. These data indicate that precious metal recovery in the Slate Creek area may require a combination of very fine grinding, gravity concentration, flotation, and chemical leaching.

Because of the inconsistent concentration of gold and PGM by panning, combinations of gravity, flotation, and leach tests are currently being conducted at the Bureau's Salt Lake City (UT)

Table 6 - Analytical data for heavy mineral concentrates panned from regolith, pulverized bedrock samples, and tailings produced by panning pulverized rock samples from the Slate Creek area, northern Chistochina Mining District

Map Number	Sample Number	Ag ppm	Au ppb	Cr pct	Fe pct	Hg ppb	Ir ppb	Os ppb	Pd ppb	Pt ppb	Rh ppb	Ru ppb	Descriptions
36	AK24393	--	--	--	--	--	--	--	--	--	--	--	Soil sample from Tertiary conglomerate regolith (visible gold removed from concentrate).
39	AK24206	--	35	0.03	11.73	--	--	--	10	<15	--	--	Pyritic diorite dike.
39	AK24206	--	34[1]	--	--	--	<1[1]	<20[1]	<20[1]	<20[1]	<5[1]	<20[2]	Pyritic diorite dike.
39	AK24206	--	15	--	--	--	--	--	5	<50	--	--	Panned tailings.
39	AK24207	--	320	.03	13.90	--	--	--	40	<15	--	--	Pyritic andesite dike.
39	AK24207	--	130[1]	--	--	--	<1[1]	<10[1]	43[1]	<20[1]	<5[1]	<20[1]	Pyritic andesite dike.
39	AK24207	--	45	--	--	--	--	--	20	<50	--	--	Panned tailings.
40	AK25185	4.3	22260	--	--	--	--	--	1027	11062	<68	--	Silicified, pyritic, andesite dike.
48	AK24481	--	160	.15	11.25	--	--	--	<2	<15	--	--	Hornblende diabase.
49	AK25919	--	327	.03	--	1800	--	--	4	15	--	--	Argillite bulk chip sample.
50	AK24265C	.4[1]	32[1]	--	--	1200	<10[1]	43[1]	43[1]	48[1]	<5	<5[1]	Hornblendite with pyrrhotite and chalcopyrite.
50	AK24265C	--	876	--	--	--	--	--	25	40	--	--	Panned tailings.
50	AK24265D	.6[1]	51[1]	--	--	1900	<10[1]	29[1]	35[1]	31[1]	<5	<5	Hornblendite.
50	AK24265D	--	82	--	--	--	--	--	30	40	--	--	Panned tailings.
51	AK25889	--	89	.006	--	110	--	--	2	<15	--	--	Hornblende diorite porphyry.
52	AK25896	--	93	.05	--	900	--	--	15	280	--	--	Pyritic hornblende diorite.
57	AK24392C	--	--	--	--	--	--	--	--	27	--	--	Hornblende gabbro with pyrite and chalcopyrite.
57	AK24392C	.3[1]	27[1]	--	--	>5000	7[1]	<10[1]	<20[1]	210[1]	<5[1]	32[1]	Hornblende gabbro with pyrite and chalcopyrite.
57	AK24392C	--	322	--	--	--	--	--	15	20	--	--	Panned tailings.
57	AK24392D	--	--	--	--	--	--	--	<20	27	--	--	Hornblende gabbro with pyrrhotite.
57	AK24392D	.2[1]	27[1]	--	--	2200	3[1]	<10[1]	<20[1]	<20[1]	<5[1]	46[1]	Hornblende gabbro with pyrrhotite.
57	AK24392D	--	208	--	--	--	--	--	20	30	--	--	Panned tailings.
57	AK25901	--	5	.02	--	1750	--	--	15	20	--	--	Gabbro with pyrite, pyrrhotite, and chalcopyrite.
58	AK24479	--	5	.05	8.20	--	--	--	15	<15	--	--	Hornblende diorite.
58	AK24479	--	7	--	--	--	<1[1]	<10[1]	22[1]	<20[1]	<5[1]	<20[1]	Hornblende diorite.

See notes at end of table

Table 6 - Analytical data for heavy mineral concentrates panned from regolith, pulverized bedrock samples, and tailings produced by panning pulverized rock samples from the Slate Creek area, northern Chistochina Mining District (continued)

Map Number	Sample Number	Ag ppm	Au ppb	Cr pct	Fe pct	Hg ppb	Ir ppb	Os ppb	Pd ppb	Pt ppb	Rh ppb	Ru ppb	Descriptions
64	AK24480	--	10	.11	7.90	--	--	--	10	<15	--	--	Hornblende diabase.
69	AK25367	--	25	.42	12.50	--	--	--	10	<15	--	--	Diorite porphyry with quartz veinlets.
74	AK25290	--	92	.03	--	140	--	--	2	<15	--	--	Diorite porphyry.
75	AK25362	--	1200	.22	14.15	--	--	--	10	<15	--	--	Diorite porphyry.
75	AK25188	1.0	4589	--	--	--	--	--	685	651	68	--	Silicified diorite.
78	AK24204	--	110	.04	9.15	--	--	--	10	<15	--	--	Diorite porphyry.
78	AK25187	1.3	7023	--	--	--	--	--	<68	1103	<68	--	Silicified diorite dike.
80	AK25364	--	180	.76	11.65	--	--	--	6	<15	--	--	Hornblende gabbro.
80	AK25365	--	10	.20	10.0	--	--	--	10	400	--	--	Diorite porphyry.
80	AK25365	--	9[1]	--	--	--	6[1]	<10[1]	35[1]	3500[1]	22[1]	<20[1]	Diorite porphyry.
81	AK25186	.5	3733	--	--	--	--	--	<68	2671	<68	--	Silicified diorite dike.
81	AK25189	.8	1678	--	--	--	--	--	<68	514	<68	--	Silicified diorite dike.
81	AK25190	1.5	3493	--	--	--	--	--	<68	479	<68	--	Silicified, pyritic, diorite dike.
81	AK25191	.5	1062	--	--	--	--	--	<68	582	<68	--	Silicified, pyritic, diorite dike.
85	AK25897	--	10	.01	--	600	--	--	2	15	--	--	Pyritic hornblende diorite.
85	AK25921	--	2240	.16	--	4500	--	--	6	<15	--	--	Argillite bulk chip sample.
86	AK25382	--	520	.03	7.10	--	--	--	10	<15	--	--	Argillite talus.
87	AK25383	--	3200	.03	7.25	--	--	--	10	<15	--	--	Argillite.
87	AK25383	--	1290[1]	--	--	--	<10[1]	<10[1]	<20[1]	<50[1]	<5[1]	<20[1]	Argillite talus.
88	AK25381	--	240	.02	7.20	--	--	--	4	<15	--	--	Argillite talus.
88	AK25381	--	25	--	--	--	--	--	<5	<50	--	--	Panned tailings.
89	AK25379	--	3800	.02	7.10	--	--	--	10	<15	--	--	Argillite talus.
90	AK25380	--	480	.03	7.30	--	--	--	10	<15	--	--	Argillite talus.
90	AK25380	--	35	--	--	--	--	--	<5	<50	--	--	Panned tailings.
91	AK25378	--	1800	.03	7.30	--	--	--	10	<15	--	--	Argillite talus.
92	AK25895	--	65	.01	--	460	--	--	2	15	--	--	Silicified andesite dike.
93	AK25894	--	20	.01	--	150	--	--	4	14	--	--	Argillite bulk chip sample.
93	AK25894	--	15	--	--	--	--	--	4	<15	--	--	Panned tailings.

See notes at end of table

Table 6 - Analytical data for heavy mineral concentrates panned from regolith, pulverized bedrock samples, and tailings produced by panning pulverized rock samples from the Slate Creek area, northern Chistochina Mining District (continued)

Map Number	Sample Number	Ag ppm	Au ppb	Cr pct	Fe pct	Hg ppb	Ir ppb	Os ppb	Pd ppb	Pt ppb	Rh ppb	Ru ppb	Descriptions
94	AK25893	--	26	.01	--	600	--	--	4	<15	--	--	Argillite Bulk chip.
95	AK25886	--	163	.01	--	35	--	--	4	20	--	--	Argillite bulk chip.
96	AK25887	--	635	.02	--	240	--	--	4	15	--	--	Pyritic argillite.
96	AK25888	--	74	.02	--	1100	--	--	4	15	--	--	Clay fault gouge.
102	AK24457	3.9	10000	--	--	5000	--	--	<5	<50	--	--	Silicified diorite.
102	AK25371	--	85	.03	7.70	--	--	--	4	<15	--	--	Silicified diorite-argillite contact.
102	AK25371	--	<5	--	--	--	--	--	<5	<50	--	--	Panned tailings.
102	AK25372	--	10	.03	7.80	--	--	--	10	<15	--	--	Silicified diorite in argillite.
102	AK25372	--	<5	--	--	--	--	--	<5	<50	--	--	Pannned tailings.
102	AK25373	--	10	.03	4.95	--	--	--	2	<15	--	--	Silicified argillite intruded by altered diorite.
102	AK25373	--	5	--	--	--	--	--	<5	<50	--	--	Panned tailings.
102	AK25374	--	400	.03	4.90	--	--	--	4	<15	--	--	Silicified argillite intruded by altered diorite.
102	AK25374	--	5	--	--	--	--	--	<5	<50	--	--	Panned tailings.
102	AK25375	--	5	.03	6.90	--	--	--	10	<15	--	--	Silicified argillite intruded by altered diorite.
102	AK25375	--	10	--	--	--	--	--	<5	<50	--	--	Panned tailings.
102	AK25376	--	90	.04	6.70	--	--	--	10	<15	--	--	Argillite wallrock.
102	AK25376	--	10	--	--	--	--	--	5	<50	--	--	Panned tailings.
119	AK25900	--	>10000	2.74	--	1300	--	--	5	15	--	--	Minus 10-mesh Tertiary conglomerate.
119	AK25900	--	46096	--	--	--	--	--	--	--	--	--	Minus 10-mesh Tertiary conglomerate.
119	AK25900E	--	10	.07	--	100	--	--	4	<15	--	--	Minus 1-in, plus 10-mesh Tertiary conglomerate.
119	AK25900F	--	6	.06	--	110	--	--	4	<15	--	--	Rounded cobbles from Tertiary conglomerate.
120	AK25899	--	724	.01	--	1750	--	--	4	15	--	--	Pyritic argillite.
128	AK24202	--	10	.05	8.70	--	--	--	2	<15	--	--	Hematite-stained diorite.
128	AK24204	--	<5	--	--	--	--	--	<5	<50	--	--	Composite of tailings from AK24202.
*	AK25209	--	570	--	--	--	--	--	35	30	--	--	Composite of tailings and slimes from AK24265 and AK24392 (map locations 50 an 57).

See notes at end of table

Table 6 - Analytical data for heavy mineral concentrates panned from regolith, pulverized bedrock samples, and tailings produced by panning pulverized rock samples from the Slate Creek area, northern Chistochina Mining District (continued)

Map Number	Sample Number	Ag ppm	Au ppb	Cr pct	Fe pct	Hg ppb	Ir ppb	Os ppb	Pd ppb	Pt ppb	Rh ppb	Ru ppb	Descriptions
*	AK25384	--	1800	.02	6.58	--	--	--	10	<15	--	--	Composite of pulverized tailings from AK25380, AK25381, and AK25382 (map locations 86, 88, and 90).
*	AK26317	--	144	.02	--	360	--	--	8	<15	--	--	Composite of tailings from AK25886, AK25889, AK25896, and AK25901 (map locations 51, 52, 57, and 95).

-- Not analyzed.

* See description for information regarding location.

\- All analyses by Bondar-Clegg, Inc, Lakewood, CO. Ag, Au, Cr, Fe, Pd, Pt, and Rh by fire assay-flame atomic absorption spectrophotometry unless indicated otherwise. Ag, Au, Pd, Pt, and Rh preconcentrated by fire assay. Hg determined by cold vapor atomic absorption spectrophotometry.

[1] Ag, Au, Ir, Os, Pd, Pt, Rh, and Ru by fire assay-neutron activation.

Research Center on four composite bedrock samples of mineralized lithologies from the study area[7]. Concentrates were produced by sulfide flotation or tabling minus-65-mesh, 1,000-gram-splits from bulk composite samples that weigh between 50 and 200 lb. Following rolling and pulverizing the concentrates and tailings to minus 200-mesh, five-gram splits of each were then leached, over heat, using various combinations of aqua regia, perchloric acid, and hydrofluoric acid.

The combination of acid-leach tests are intended to determine which minerals in a sample contain gold. Free gold and gold contained in sulfide minerals are dissolved by aqua regia. Free gold, gold in sulfide minerals, and gold contained in carbonaceous material are dissolved by leaching with aqua regia and perchloric acid. Free gold, and gold in sulfide minerals, carbonaceous material, and silicate minerals are all dissolved when leached with aqua regia, perchloric acid, and hydrofluoric acid.

The results of tabling, sulfide flotation, and acid-leach tests on a composite argillite bedrock sample indicate that gold is present in more than one mineral in argillite from Miller Gulch and Quartz Creek. The composite sample consisted of pyritic argillite from map locations 93, 94, 95, 124, and 147. The tabled concentrate contained 0.008 oz/st (274 ppb) Au and the tabled tailings contained 0.005 oz/st (171 ppb) Au. Normally, free gold and other heavy minerals would be present in the tabled concentrate. A bulk sulfide flotation concentrate from another 1,000-gram-split of the composite sample contained 0.0084 oz/st (288 ppb) Au and the flotation tailings, however, contained 0.012 oz/st (411 ppb) Au. These data indicate that free gold is present and that some gold is present in sulfide minerals. No gold was detected in acid solutions after leaching the flotation concentrate and flotation tailings. Because only a five-gram split was leached, and possibly owing to erratic gold distribution, the leach tests may be inconclusive. Acid and cyanide leach tests are currently being conducted on larger samples.

The presence of less gold in the argillite concentrate than in the argillite tailings indicates that gold may be present in carbonaceous material, as well as in other minerals and alloys. The aqua regia-perchloric leach test did not confirm this, but again, the five-gram split may have been too small for the leach tests to be conclusive. For these reasons, cyanide leach tests are being conducted on larger splits from the four composite samples at the Salt Lake City Research Center. Also, PGM analyses are being performed on the samples described above and on the concentrates to be produced by the cyanide leach tests.

A tabled concentrate from a sulfide-bearing gabbro and clinopyroxenite sill, at the head of Quartz Creek (map locations 145 and 146), contained 0.006 oz/st (205 ppb) Au. The midlings, which, compared to the tailings and concentrate, are generally intermediate in specific gravity, contained 0.003 oz/st (103 ppb) Au. The tailings contained 0.002 oz/st (68 ppb) Au. No gold was detected in the acid solution following leaching of five-gram splits of the tabled concentrate and tailings from this composite sample.

A tabled concentrate from a composite sulfide-bearing gabbro sample at the ridgecrest between Miller Gulch and the Chistochina Glacier (map locations 57 and 63) contained 0.033 oz/st (1130 ppb) Au. The midlings contained 0.005 oz/st (171ppb) Au and the tailings contained 0.006 oz/st (205 ppb) Au. Duplicate aqua regia-perchloric acid-leach solutions from five-gram splits of the tabled concentrate contained 0.0015 oz/st (50ppb) and 0.002 oz/st (80 ppb) Au. The other acid-leach solutions from this composite sample contained less than 50 ppb Au.

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[7] Results reported by W.R. McDonald, Metallurgist, Bureau of Mines Salt Lake City (UT) Research Center.

A tabled concentrate from the 60-ft-wide diorite porphyry and syenodiorite porphyry dike on Miller Gulch (map location 74) contained 0.02 oz/st (685 ppb) Au. The midlings and tailings both contained 0.001 oz/st (34 ppb) Au. Duplicate aqua regia-perchloric acid-leach solutions from five-gram splits of the tabled concentrate contained 0.003 oz/st (100 ppb) and <0.006 oz/st (<50 ppb) Au. The other acid-leach solutions from this composite sample contained less than 50 ppb gold.

Concentration of gold and PGM by panning pulverized rock samples (table 6), and the reported gold analyses for the composite samples indicate that gold and PGM are erratically distributed at the mineral-grain scale. Consequently, conventional sampling and analytical procedures in which a 30 gram or smaller split is analyzed may not be appropriate for gold and PGM investigations in the Slate Creek area.

No anomalous gold or PGM were detected in three stream sediment samples collected south of Slate Creek (table 7). The high copper content in sample AK21623 (map number 101) probably reflects the presence of accessory chalcopyrite and malachite.

Analyses of the pan concentrate and sluice box concentrates show that gold is much more abundant than PGM. The high silver content in amalgamation rejects separated from placer gold concentrates indicates that silver may be present in minerals other than native gold. The mercury analyses reflect the presence of cinnabar which is present in all the heavy mineral concentrates. The presence of greater than 10,000 ppb Au in a five-gram sample (AK25600, table 7) of placer cinnabar grains is further evidence for the geochemical association between gold and mercury in bedrock in the area.

A pan concentrate sample from Tertiary conglomerate regolith from map number 119 contained 1.34 oz/st (46,096 ppb) Au, but, virtually no PGM (table 6). This supports earlier workers assertions that some of the gold in the district was derived from the roundwash but does not support the conclusion that platinum is contained in the roundwash (7, 20-22).

MINERALOGY

Numerous samples, including placer concentrates from sluice boxes, rock samples, grain mounts, mineral grains, and concentrates produced by panning gold- and PGM-bearing rocks were submitted to various laboratories for electron microprobe and scanning electron microscope analysis.

Platinum-group metal-bearing minerals identified in placer concentrates include tetraferroplatinum (fig. 9) and osmiridium (fig. 10). Three microprobe analyses on the tetraferroplatinum grain in figure 9 gave very similar results and indicate a composition of about 96 pct Pt and 4 pct Fe. SEM and microprobe analyses for other placer tetraferroplatinum grains from Miller Gulch and Big Four Gulch indicated compositions between 83 and 85 pct Pt and between 15 and 17 pct Fe. SEM analyses indicate the presence of traces of palladium, rhodium, and ruthenium in the alloy. Semi-quantitative X-ray diffraction and X-ray fluorescence analyses on several platinum-iron alloy grains from Miller Gulch by W.S.Roberts[8] indicated compositions of 70 pct Pt, 23 pct Fe and traces of palladium, rhodium, and copper.

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[8]Physical Scientist, formerly employed by U.S.Bureau of Mines, Juneau, AK.

Table 7 - Analytical data for stream sediment samples, sluice box concentrates, and pan concentrates from the Slate Creek area, northern Chistochina Mining District

Sample Number	Ag ppm	Au ppb	Co ppm	Cr ppm	Cu ppm	Fe pct	Hg ppb	Ni ppm	Pb ppm	Pd ppb	Pt ppb	Rh ppb	Zn ppm	Descriptions
AK21623	<0.3	<7	<2	--	500	--	--	52	<80	--	--	--	--	Stream sediment sample (map number 101).
AK21993	--	1.1E5	--	--	--	--	--	--	--	68	10479	--	--	Minus 4-mesh magnetic concentrate from upper Slate Creek placer operation.
AK21996	<.3	<7	<2	--	180	--	--	<8	<80	--	--	--	73	Stream sediment sample (map number 98).
AK21998	.6	<7	<2	--	<5	--	--	76	<80	--	--	--	110	Stream sediment sample (map number 97).
AK24363	.4	>10000	--	--	--	--	5000	--	--	15	<50	--	--	Pan concentrate sample from Miller Gulch (map number 77).
AK24363	--	8017	--	--	--	--	--	--	--	--	--	--	--	Do.
AK24379	.5	>10000	--	--	--	--	1850	--	--	5	<50	--	--	Do.
AK24379	--	30445	--	--	--	--	--	--	--	--	--	--	--	Do.
AK24483	--	>10000	--	1600	--	9.55	--	--	--	10	<15	--	--	Pan concentrate of argillite bedrock fault gouge, upper Slate Creek (map number 132).
AK24483	--	1.34	--	--	--	--	--	--	--	--	--	--	--	Do.
AK25183A	.4	3288	--	--	--	--	--	--	--	479	6.8E4	377	--	Magnetic fraction from amalgamation rejects, Miller Gulch sluice box concentrate.
AK25183B	>50	1.5E6	--	--	--	6.7E6	--	--	--	31884	4.5E6	--	--	Non-magnetic fraction of amalgamation rejects from 500 oz placer gold concentrate from Miller Gulch.
AK25184	130	1.3E5	--	--	--	--	--	--	--	1712	2.2E5	890	--	Amalgamation rejects from 500 oz placer gold concentrate from Miller Gulch.
AK25210	--	>10000	--	--	--	--	--	--	--	--	200	--	--	Magnetic concentrate from Slate Creek placer operation.
AK25210	--	>20000	--	--	--	--	--	--	--	--	--	--	--	Do.
AK25600	113	>10000	--	--	--	--	--	--	--	<15	<1	--	--	5 grams of cinnabar grains picked from Miller Gulch pan concentrate and sluice box concentrate.
AK25601	85.7	2.4E5	--	--	--	--	--	--	--	685	68836	--	--	Minus 65-mesh amalgation rejects from 500 oz placer gold concentrate from Miller Gulch.
AK25602	4458	1.5E6	--	--	--	--	--	--	--	34247	4.1E6	--	--	Plus 65-mesh amalgamation rejects from 500 oz placer gold concentrate from Miller Gulch.

-- Not analyzed.

- Ag, Au, Pd, Pt, and Rh determined by fire assay-flame atomic absorption spectrophotometry. Co, Cr, Cu, Fe, Ni, Pb, and Zn by flame atomic absorption spectrophotometry. Hg by by cold vapor atomic absorption spectrophotometry. All analyses by Bondar-Clegg, Inc., Lakewood, CO.

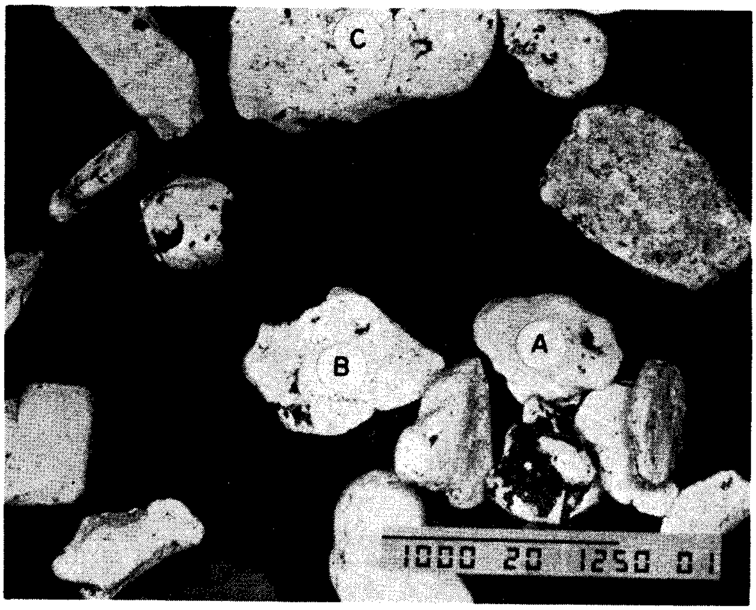

Figure 9. - Typical platinum-iron alloy (tetraferroplatinum) grains from Miller Gulch placer concentrate. The letters A-C correspond to microprobe analyses; all contained about 96 pct Pt and 4 pct Fe. Scale bar is 1,000 microns (1 millimeter).

Figure 10. - Osmiridium grain recovered from argillite talus at Miller Gulch (map number 88). Grain is 3 millimeters along longest axis.

Other minerals found in the placer concentrates from the district include abundant chalcopyrite, cinnabar, hematite, garnet, ilmenite, magnetite, pyrite, pyrrhotite, native lead and mercury. Accessory minerals include arsenopyrite, apatite, barite, chromite, cobaltite, epidote, galena, rutile, scheelite, sphene, and zircon.

A 1-micron-long tetraferroplatinum grain, with 90 pct Pt and 10 pct Fe, was observed during SEM examination of a quartz grain in pyritic argillite from map number 96.

A mineral containing about 25 pct Cu, 4 pct Zn, 7 pct Ag, and 4 pct Au was identified by SEM in silicified, pyritic diorite from map number 7. Several silver-mercury amalgam blebs were observed in syenodiorite from map number 74.

Minute particles of gold (from 3 to 60 microns across), and gold-mercury amalgam, were observed in polished sections of hornblendite and silicified dike rocks and grain mounts of heavy mineral concentrates produced by panning pulverized rock samples from map locations 50 and 81 (table 6). Gold and gold-mercury amalgam in these samples is included as discrete very fine microscopic grains in pyrite, chalcopyrite, Ca-amphibole and pyroxene. Other minerals observed in the gold-bearing samples include arsenopyrite, pentlandite, hematite, galena, molybdenite, scheelite, zircon, rutile, smithsonite, barite, an unidentified rare-earth mineral, quartz, plagioclase, orthoclase, pyroxene, and amphibole.

Several very bright osmiridium grains were picked from sluice box and panned concentrates from Miller Gulch and Slate Creek. Also, a 2-mm by 2-mm by 3-mm osmiridium grain (fig. 10) was recovered in a concentrate produced by panning a pulverized split of argillite talus from the steep slopes above Miller Gulch (map location 88, tables 3 and 6). The talus was screened and washed at 10-mesh (2-mm opening), prior to pulverizing. SEM analyses of numerous osmiridium grains from Miller Gulch and Slate Creek indicate compositions of these grains are all very similar with about equal portions of osmium and iridium, and traces of palladium, rhodium, and ruthenium.

The presence of osmiridium in the placer samples and panned heavy mineral concentrates demonstrate that osmium and iridium are indeed present in the area. The reported levels of osmium, iridium, and ruthenium in geochemical analyses listed in table 6 may be artificially low as a result of volatilization of these three metals during fire assay pre-concentration of samples prior to analysis (15).

Copper-gold alloy (fig. 11) was observed in several placer concentrate samples from Miller Gulch and upper Slate Creek. A 0.6 gram nugget from upper Slate Creek is cored by electrum with 90 pct Au and 10 pct Ag (fig. 12). Between the core and the rim is an intermediate zone of tetra-auricupride with 77 pct Au and 23 pct Cu. The rim of the nugget is auricupride with 56 pct Au and 44 pct Cu. Native gold (silver-gold alloy), with up to 16 pct Ag, and relatively pure native copper nuggets also are found in the concentrates.

Dendritic native gold was observed in native lead in a grain picked from a Miller Gulch placer concentrate (fig. 13). Another grain from the same concentrate shows a complex intergrowth of lead-gold, copper-silver-gold alloys, and electrum (fig. 14). Not shown in figures 9-14, but frequently observed in the placer concentrates, are copper nuggets with relict chalcopyrite cores and grains containing copper cores with chalcopyrite rims. The alloy and mineral compositions can best be explained by supergene processes. The observed textures and the complex alloys are neither typical of magmatic or hydrothermal mineral deposits and they probably resulted from elemental leaching and metal replacement by percolation of meteoric waters through the alluvial gravels, talus, and highly shattered bedrock.

A minute platinum-iron alloy grain was observed along a grain boundary between ilmenite, partially altered to sphene, and magnetite in a mafic rock fragment in a Miller Gulch placer concentrate (fig. 15). This mineral assemblage resembles those observed in igneous bedrock in the study area.

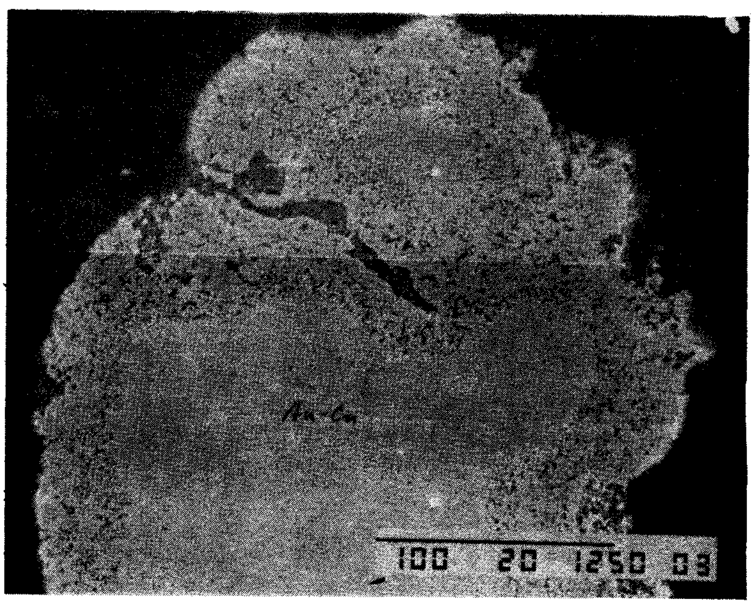

Figure 11. - Back-scatter SEM image of copper-gold alloy from Miller Gulch placer concentrate. The dense core is gold-rich (90 pct Au and 10 pct Cu) and the sponge-textured border is more copper-rich, but still dominated by gold (56 pct Au and 44 pct Cu). Scale bar is 100 microns (0.1 millimeter).

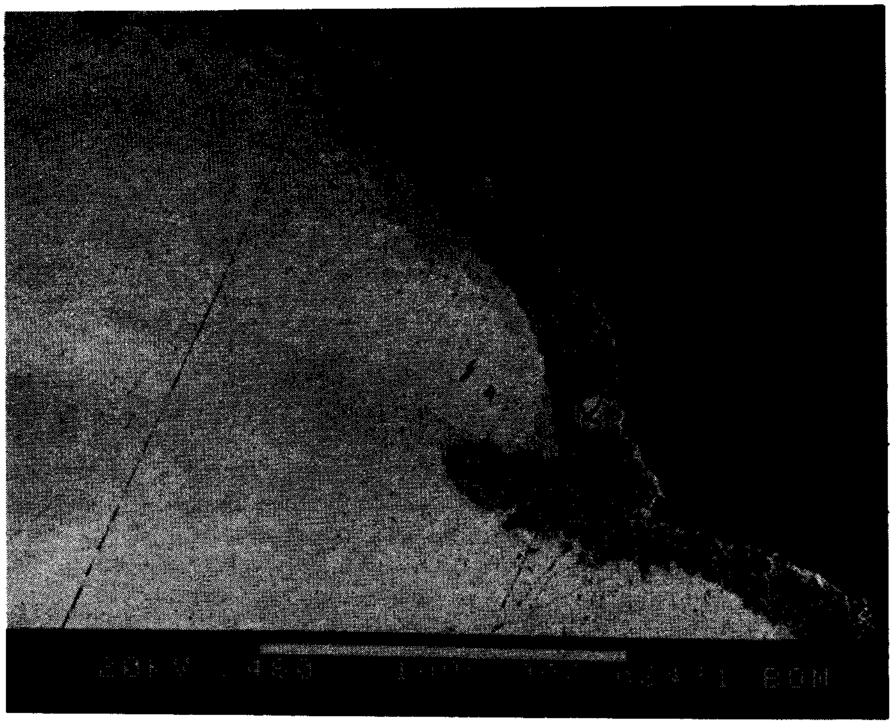

Figure 12. - Back-scatter SEM image of concentrically-zoned silver-gold and copper-gold alloy nugget from upper Slate Creek. Bright core contains electrum with 90 pct Au and 10 pct Ag. Light gray, intermediate band in upper center is tetra-auricupride with 77 pct Au and 23 pct Cu. Dark, outermost band is auricupride, with 56 pct Au and 44 pct Cu. Scale bar is 100 microns (0.1 millimeter).

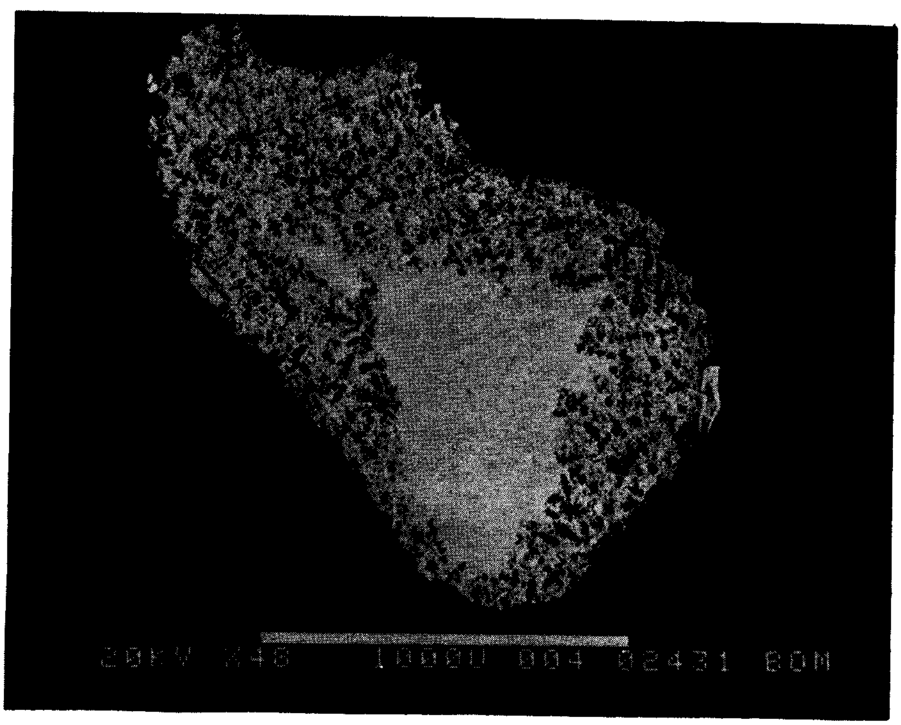

Figure 13. - Back-scatter SEM image of dendritic native gold in native lead placer grain from Miller Gulch. Traces of silver, antimony, sulfur, and arsenic were also detected during energy-dispersive X-ray analysis. Scale bar is 1,000 microns (1 millimeter).

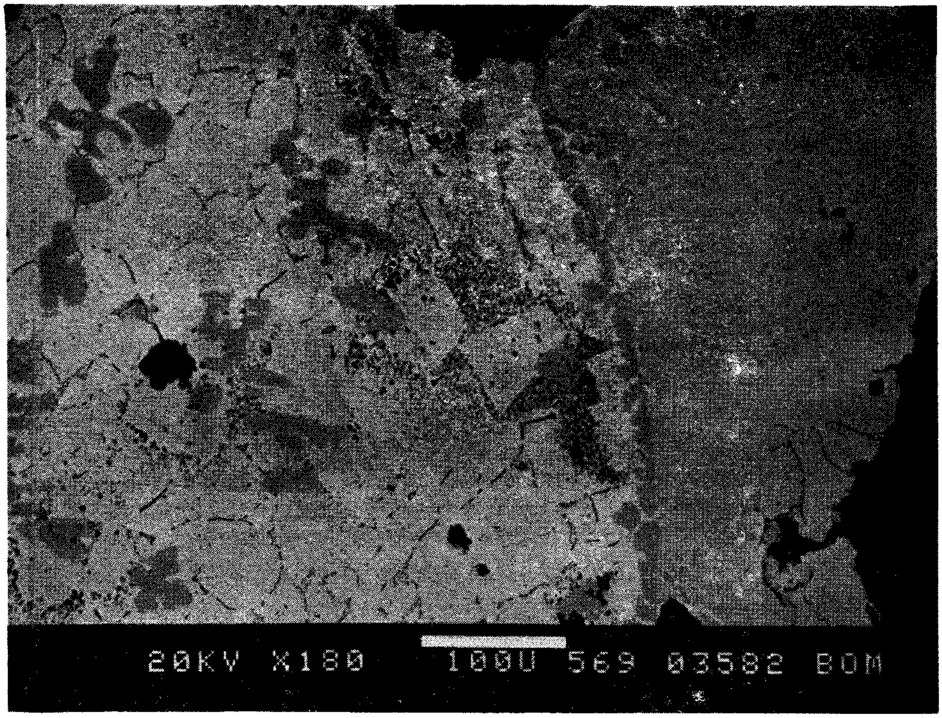

Figure 14. - Back-scatter SEM image of placer grain from Miller Gulch showing complex intergrowth of electrum, lead-gold alloy, and copper-silver-gold alloy. The electrum (medium-gray, on far right) contains 96 pct Au and 4 pct Ag. The copper-silver-gold alloy (dark gray) with 80 pct Au, 17 pct Ag, and 3 pct Cu, separates the lead-gold alloy and electrum and occurs as blebs in the lead-gold alloy.

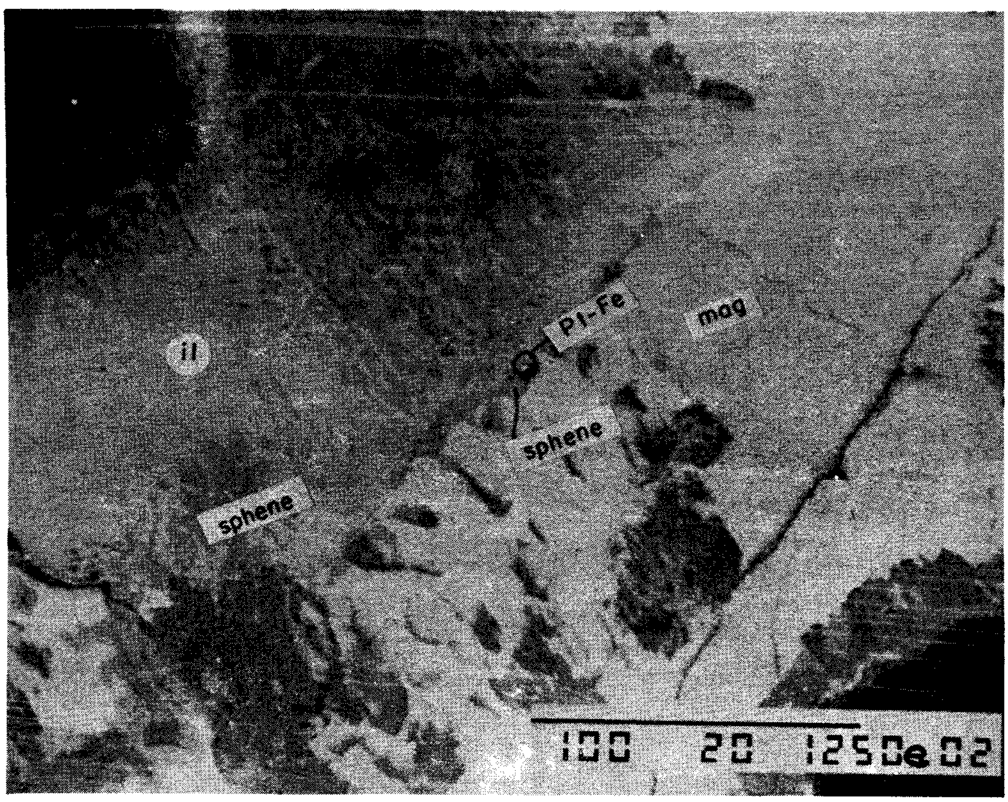

Figure 15. - Back-scatter SEM image of a minute platinum-iron (Pt-Fe) alloy grain along ilmenite (il)-magnetite (mag) grain boundary in mafic rock fragment from Miller Gulch placer concentrate. Ilmenite is partially altered to sphene. Scale bar is 100 microns (0.1 millimeter).

A 7-micron gold particle was observed in a quartz grain from a crushed argillite bedrock sample from Miller Gulch (fig. 16) and numerous smaller gold particles were observed in a pyrite grain from the same sample (fig 17).

Figure 16.- Back-scatter SEM image of equant 7-micron gold particle in quartz fragment from crushed argillite sample from Miller Gulch. Scale bar is 20 microns (0.02 millimeters).

Figure 17. - Back-scatter SEM image of numerous bright gold inclusions in pyrite from crushed argillite sample from Miller Gulch. Scale bar is 20 microns (0.02 millimeters).

DISCUSSION

Placer gold production in the upper Slate Creek area is restricted to the Slate Creek Valley and streams north of Slate Creek and the Chisna River, where argillite has been intruded by igneous sills, stocks, and dikes. The placer gold is partially derived from Tertiary conglomerate, which, overlies the argillite and igneous rocks. The igneous rocks have thermally altered the argillite host rocks, and have, themselves, been subsequently altered and partially replaced by calcite and silica. The geochemical and mineralogic data and the close spatial relationship of the placer deposits to argillite intruded by igneous rocks indicate that PGM, mercury, copper, lead, and some of the placer gold, as well as many of the other observed sulfide and rock-forming minerals, were locally derived by erosion of the argillite and igneous rocks.

Minor amounts of platinum-iron alloy and osmiridium are generally found in concentrates from streams in the area, including Big Four Gulch, Miller Gulch, upper and lower Slate Creek, and Ruby Gulch. Placer concentrates from these streams also contain abundant chalcopyrite, cinnabar, garnet, hematite, ilmenite, magnetite, and pyrite, as well as native copper, lead, and mercury. Gold, copper, and mercury typically combine as an amalgam in the placer concentrates. Scanning electron microscope and energy-dispersive X-ray (EDAX) analyses indicate that the gold contains variable amounts of silver, and that natural alloys of gold, silver, lead, and copper are also present. Also chalcopyrite is replaced by native copper. Many of these alloys and mineral intergrowths appear to be the result of supergene processes. Accessory minerals in placer concentrates from the area include arsenopyrite, apatite, barite, chromite, cobaltite, epidote, galena, scheelite, sphene, and zircon. Assays of nonmagnetic fractions of sluice box concentrates from Miller Gulch indicate the presence of over 1 oz/st silver (AK25183B and AK25184, table 7). X-ray analysis of another placer concentrate from Miller Gulch (AK21250, table 7) indicated between 5 and 7 pct Ag.

Analytical data indicate that gold and PGM are erratically distributed in bedrock in the area and that PGM are concentrated in igneous dikes and sills. Visible gold particles were identified in heavy mineral concentrates produced by panning pulverized samples of argillite and several igneous rocks in the Slate Creek area. Also, gold was identified in pan concentrates from several samples of decomposed Tertiary conglomerate collected from the ridges above Miller Gulch and Slate Creek. Anomalous copper and mercury were detected in pan concentrates of pulverized samples from the various rock types in the area and in unconcentrated bedrock samples of argillite and igneous rocks that intrude the area north of the Slate Creek and upper Chisna River Valleys. Similar geochemical enrichment of copper, gold, mercury, platinum, and silver was observed in the argillite and igneous rocks. These relationships indicate that hydrothermal fluids associated with intrusion of the igneous rocks, and perhaps subsequent supergene fluids, permeated the fractured argillite, resulting in similar geochemical signatures in both rock types.

Calcite veinlets are widespread in the igneous rocks and in metamorphosed and hydrothermally altered argillite wallrock, and are believed to be related to gold concentration in the area. Quartz veinlets are also present but are less abundant than are the calcite veinlets. The calcite and quartz veinlets could have formed during low-grade dynamic metamorphism or thermal alteration of the country rock as has been demonstrated in Cretaceous Valdez Group flysch deposits in south-central Alaska (13,23,37,38,44) and in many other auriferous regions in the world. Boyle (4) attributes the presence of gold-bearing quartz veins in metamorphosed argillite in the Yellowknife gold deposits, Northwest Territories, to high-pressure, low-temperature metamorphism and correlates the abundance of volatiles, including water, carbon dioxide, and sulfur, to lower metamorphic grade (e.g. greenschist facies rocks). In that region, however, gold is more abundant in higher-grade metamorphic rocks. Because calcite and quartz veinlets are present in the Cretaceous-Tertiary (?) igneous rocks and are most abundant in the upper Jurassic-Cretaceous sedimentary rocks marginal to the igneous rocks, it is concluded that they are, at least in part, the result of intrusion of the dikes and igneous sills. Calcite veinlets were observed to contain hematite cores at the margins of several diorite dikes in the Miller Gulch and upper Slate Creek areas and on the south side of the upper Chistochina river. Also, hematite is ubiquitous throughout the study area and may be further indicative of the physical chemistry of fluids that were associated with the intrusive rocks, and which, concentrated gold in the igneous and sedimentary rocks in the area.

It should be noted that no greenschist facies rocks are present in the study area, and quartz-calcite veins are mostly limited to less than 1-in widths. Quartz-calcite alteration is mostly concentrated along dike margins and in argillite wallrock, adjacent to igneous contacts.

In his summary of gold deposits in turbidites, Boyle (5) asserts that thermal alteration of turbidite sequences by intrusion of igneous rocks can serve essentially the same role as regional metamorphism in forming turbidite-hosted gold deposits. Also, the chemical signature and mineralogical assemblages observed in the northern Chistochina Mining District are similar to those described by Boyle (5).

RECOMMENDATIONS

Geophysical surveys including magnetic, electromagnetic, and other methods may be helpful in ascertaining the subsurface configuration of dikes and intrusive contacts, where mineralization is apparently concentrated. Additional sampling and possibly subsurface exploration by diamond drilling should be concentrated at locations of anomalous gold, PGM, and mercury identified in this report. These include numerous sites in the Miller Gulch drainage (tables 3 and 6 and fig. 2), the diorite porphyry and syenodiorite porphyry dikes and argillite wallrock on Miller Gulch (map numbers 73-75), altered sulfide-bearing igneous rocks on the ridge to the west of Miller Gulch (map numbers 54, 55, and 57), the resistant indurated argillite outcrop to the east of Miller Gulch (map number 104, table 6 and fig. 2), and the pyrite-rich contact zone between argillite and the differentiated igneous rocks on upper Quartz Creek (map locations 145 and 146).

Additional mapping and sampling should be conducted during late summer months, after the snow cover has melted on north-facing ridges, to determine the extent, configuration, composition, and precious metal content of mafic and ultramafic rocks on the south side of the Chistochina Glacier, at the heads of upper Slate Creek and Quartz Creek. Also, more detailed sampling should be done in the Tertiary conglomerate.

Additional metallurgical and chemical testing are warranted to determine how gold and PGM are contained in, and might be recovered from, bedrock material in the Chistochina Mining District.

Mercury vapor surveys may also prove to be an effective means of identifying buried mineralized zones.

Because gold was detected in regolith samples, Biogeochemical sampling for *Bacillus cereus*, as described by Sporleder (42) or conventional soil sampling and chemical analysis with and without pan concentration, might aid in delineating additional prospects. It is suggested that future investigations in the area would benefit from an orientation survey designed to demonstrate exactly what types of sampling and analysis are best suited for gold and PGM exploration in the district.

Isotopic and fluid inclusion studies might be useful in ascertaining the role of devolatilization and metamorphic hydrothermal fluids and in the transport and deposition of precious and other valuable metals in the district.

In addition to the previous recommendations, this investigation has demonstrated that more comprehensive geochronologic data is needed to accurately interpret the history and evolution of the geology and ore deposits in the region. It is suggested that argon isotopic age dates or neodymium-samarium age dates be obtained for igneous rocks in the region during future studies.

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