PLATINUM AND PALLADIUM IN SOME MAFIC/ULTRAMAFIC ROCKS FROM THE RABBIT CREEK AREA IN THE NOATAK QUADRANGLE, ALASKA

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Donald P. Hodel, Secretary

BUREAU OF MINES

Robert C. Horton, Director

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ppb	parts per billion
ppm	parts per million
pct	percent

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By Thomas C. Mowatt[1/] and Uldis Jansons[2/]

ABSTRACT

Preliminary Bureau of Mines studies of mafic igneous rocks collected from the Rabbit Creek area, northwestern Alaska, indicated concentrations of platinum (412 to 1,406 ppb) and palladium (343 to 892 ppb) in five of eight samples analyzed. The samples represent boulders and cobbles of mafic/ultramafic rocks from this locality. They are not from outcrop.

Petrologically, (on the hand specimen scale) the samples are crudely to well-layered and are troctolitic ± gabbroic in character, with primary igneous mafic minerals strongly altered. Small patches of interstitial sulfide minerals, including chalcopyrite, bornite, pyrrhotite, pyrite, and covellite are associated with these altered zones and elsewhere through the specimens. Copper values ranged from 0.1 to 0.3 pct in samples analyzed semiquantitatively; nickel, cobalt, and chromium contents are low.

Chemical, mineralogic, and petrographic relationships suggest that the rocks of similar character outcropping in northwestern Alaska could also be considered as prospective for concentrations of platinum, palladium, and copper.

INTRODUCTION

This report presents the results of preliminary chemical and petrographic studies of a suite of mafic and ultramafic rock samples collected during field investigations carried out by the Bureau of Mines (Bureau) in the western

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Brooks Range, Alaska (fig. 1). The field work, carried out in 1976, was part of the Bureau's Mineral Land Assessment activities related to Alaskan D-2 lands. This is a preliminary report to release the information on appreciable geochemical concentrations of platinum group elements (PGE). More detailed petrographic, mineralogic, and geochemical work currently is in progress.

Rounded cobbles and boulders in the stream bed and banks of the sample site on Rabbit Creek included a large proportion of medium- to coarse-grained banded/layered mafic/ultramafic igneous rocks. The bedrock sources of these samples has not been identified. The size of the boulders and cobbles would suggest rather limited transport. Discernible sulfide minerals were associated with some of these materials. Samples representative of the sulfide-bearing rocks were collected.

While areas of mafic/ultramafic rocks are present in the western Brooks Range, no similar concentrations of PGE and associated sulfide minerals have been reported. This may merely reflect a lack of detailed investigation. A few PGE occurrences have been reported as concentrations in finer-grained stream sediments elsewhere in the region, (for example, Avan River area) in proximity to bedrock materials similar to those reported on in this study. Sulfide mineralization has been recognized petrographically in several areas between the Avan and Kelly Rivers. The sulfides are associated with mafic igneous rocks of gabbroic character (Mowatt, unpublished data). These occurrences have not been studied further as yet.

ACKNOWLEDGMENTS

The sample preparation work and the petrographic analyses were done at the Bureau's facility in Juneau, Alaska. The platinum and palladium analyses were carried out at the Bureau's Reno Research Center, Reno, Nevada.

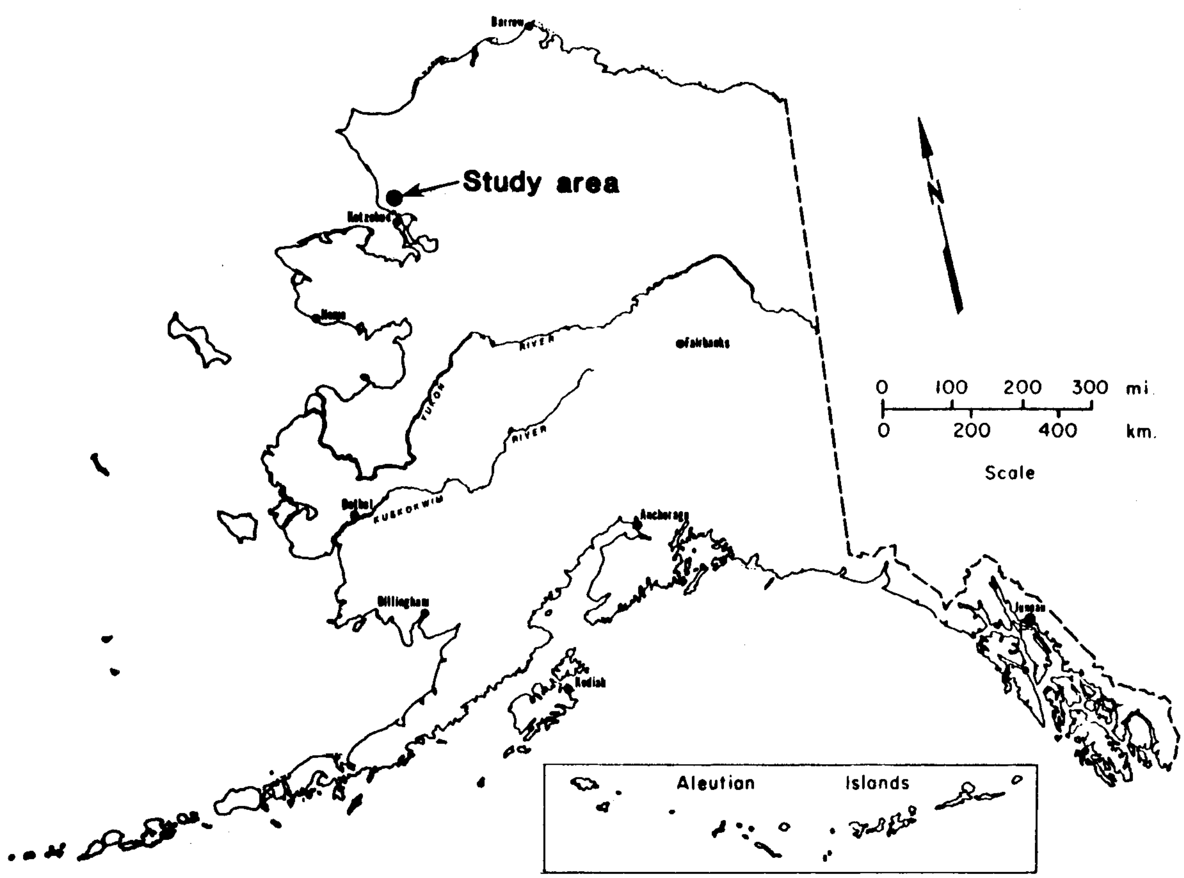

Figure 1. Location of the Rabbit Creek study area, Noatak Quadrangle, northwest Alaska.

The Rabbit Creek area was visited briefly on June 22, 1976, by a party including the authors, together with C. Mayfield and I. Tailleur (U.S. Geological Survey).

BUREAU OF MINES INVESTIGATION

The sample locality lies within the Rabbit Creek drainage system, in the Noatak C-3, 1:63,360 quadrangle map area, northwestern Alaska (fig. 2). While searching for reported base-metal occurrences in sedimentary rocks along Rabbit Creek, mafic/ultramafic rocks were also sampled. Some contained minor visible amounts of sulfide minerals.

Subsequent laboratory work addressed the potential for significant concentrations of platinum-group elements, chromium, cobalt, and nickel in these rocks.

ANALYTICAL WORK

Examination of sampled materials with the binocular microscope, followed by petrographic examination in transmitted and reflected light, confirmed the field observations regarding sulfide minerals. Selected portions of the sulfide-bearing zones of eight samples were reduced to -100 mesh pulps, using a ceramic swing mill, and submitted for analysis. Analytical methods included semiquantitative optical emission spectrometry, x-ray fluorescence, wet chemical procedures, and a combined fire-assay optical-emission spectrographic technique.

Fire-assay optical-emission spectrographic analytical results and selected optical-emission spectrometric results are presented in table 1. Only two, platinum (Pt) and palladium (Pd), of the six PGE (Pt, Pd plus rhodium, iridium, osmium, ruthenium) were determined in this preliminary investigation.

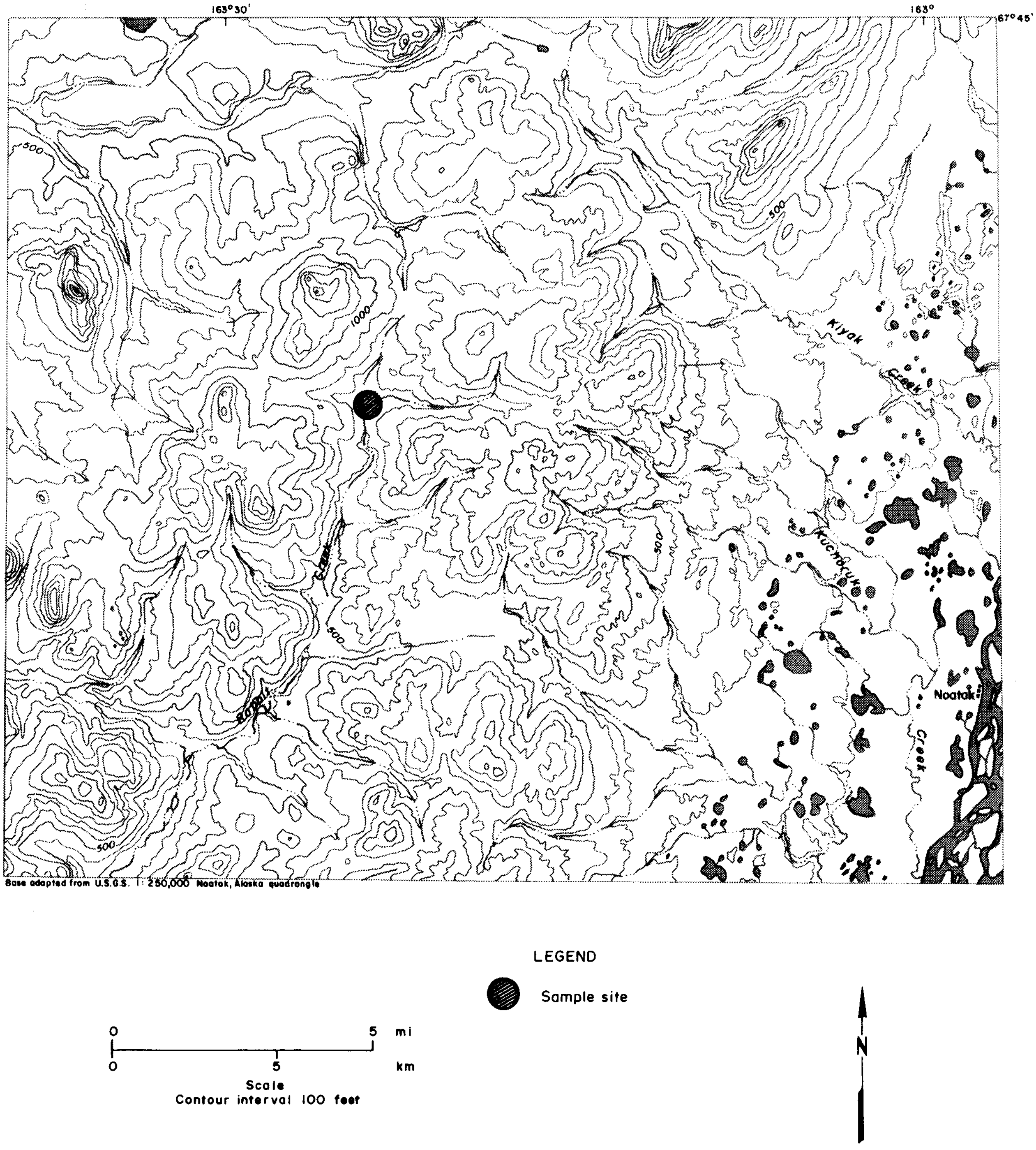

Figure 2. Location of samples discussed in present study: Noatak C-3 Quadrangle (1:63,360), USGS, 1955

ANALYTICAL RESULTS

Eight samples were analyzed to determine their platinum, palladium, gold, copper, nickel, chromium, cobalt, iron, and magnesium contents. The analytical results are shown in table 1.

Platinum (412 to 1,406 ppb) and palladium (343 to 892 ppb) were detected in five samples. Gold (206 to 209 ppb) was detected in four samples, copper was present in values between 1,000 and 3,000 ppm in five samples; three contained 6 ppm copper each. Nickel values ranged from 40 to 200 ppm; cobalt values ranged from 10 to 40 ppm; iron from 3 to 6 pct; and magnesium from 1 to 3 pct. Samples with high platinum and palladium values also had high gold and copper values, with low nickel, cobalt, iron, and magnesium. The suggestion is that the precious metals are associated with the copper minerals.

GEOCHEMICAL RELATIONSHIPS

The Rabbit Creek data were compared with PGE values in recent literature (2)[3/]. These comparisons seem to indicate that the Rabbit Creek materials merit serious scrutiny with regard to potentially significant concentrations of PGE.

Material listed by Naldrett and Cabri (2) contain similar or higher values of platinum and/or palladium than the Rabbit Creek samples. The cited values are representative of monomineralic materials, and/or from ore deposits. Numerous materials are also listed by Naldrett and Cabri (2) which are similar to or lower in platinum and/or palladium content than the Rabbit Creek materials. The latter were intended to be representative of the obviously sulfide-bearing horizons, in particular, of the rocks sampled. However, as can be noted from the relatively low modal percentage of sulfides

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

TABLE 1. - Partial chemical analyses, Rabbit Creek, Alaska, samples
(Analyses performed at Reno Research Center, Reno, Nevada)

Sample Number	Platinum[1] (ppb)	Palladium[1] (ppb)	Gold[1] (ppb)	Copper[2] (ppm)	Nickel[2] (ppm)	Chromium[2] (ppm)	Cobalt[2] (ppm)	Iron[2] (wt.pct)	Magnesium[2] (wt.pct)
J 77-57	ND[3]	ND	ND	6	90	20	30	6.0	2.0
J 77-58	ND	ND	ND	6	100	500	40	6.0	3.0
J 77-87	686	892	240	2000	90	8	10	4.0	1.0
J 77-109	1166	858	206	2000	50	8	10	4.0	1.0
J 77-112	1406	755	240	3000	40	8	10	3.0	2.0
J 77-128	ND	ND	ND	6	90	500	30	6.0	2.0
J 77-140	412	343	309	3000	200	200	30	5.0	2.0
J 77-150	1029	583	ND	1000	60	8	20	5.0	2.0

1. Fire-assay/optical-emission spectrographic analyses of one-half assay ton (15 grams). The results reported as troy oz./short ton, have been recalculated to ppb (parts per billion). Minimum detection limits are 69 ppb (platinum, palladium), 35 ppb (gold).

2. Optical-emission spectrometric semi-quantitative analyses.

3. "ND" = not detected.

recognized microscopically in the Rabbit Creek rocks (visually estimated to range from less than 1 to 5 pct), the high platinum and palladium values reported essentially represent concentrations in silicate rocks, with minor associated sulfide and oxide phases. This is corroborated by the 1,000 to 3,000 ppm copper concentrations reported in the Rabbit Creek samples. A generalized trend recognized between the concentrations of copper and PGE might suggest genetic affiliation (fig. 3).

The platinum (Pt) - palladium (Pd) - gold (Au) relationships in the Rabbit Creek samples are presented in table 2.

The general categories of mafic/ultramafic complexes developed by Naldrett and Cabri (2) have defined element ratios. Comparisons of the Pt/Pt + Pd, and Au/Pt + Pd + Au ratios with data on other occurrences worldwide (2) are summarized in table 3. The comparative data do not suggest unambiguous assignment of the Rabbit Creek samples to any genetic type. The values of both ratios for both the "Alpine complexes" and the "Alaskan-type Complexes" are sufficiently dissimilar to the ratios from Rabbit Creek as to indicate that the Rabbit Creek rocks most likely do not belong to either of these categories.

The Au/Pt + Pd + Au ratios of the Rabbit Creek samples most closely resemble those from the "Nickel-Copper Sulfide Ores" category, and do not overlap the ratios given for "Layered Complexes, Excluding Heavily Mineralized Zones". The wide ranges for the Pt/Pt + Pd ratios given for "Layered Complexes, Excluding Heavily Mineralized Zones", and for "Nickel-Copper Sulfide Ores" permit assignment of the Rabbit Creek samples to either of these categories. The Rabbit Creek ratio values for Pt/Pt + Pd are closely matched by several localities within each of these latter two categories, as displayed in table 4.

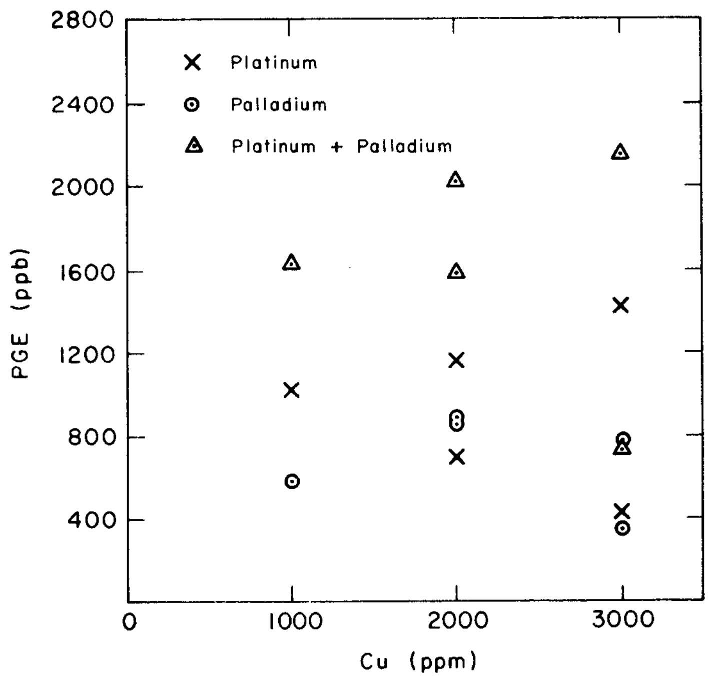

Figure 3.--Plot of PGE as function of copper content of Rabbit Creek, Alaska, samples.

TABLE 2. - Platinum - palladium - gold relationships in Rabbit Creek, Alaska, samples

Sample Number	Pt + Pd (ppb)	Pt / Pt + Pd	Au / Pt + Pd + Au
J 77- 57......	-	-	-
J 77- 58......	-	-	-
J 77- 87......	1578	0.44	0.13
J 77-109......	2024	0.58	0.09
J 77-112......	2126	0.65	0.10
J 77-128......	-	-	-
J 77-140......	755	0.55	0.29
J 77-150......	1612	0.64	-

TABLE 3. - Comparison of platinum (Pt) - palladium (Pd) - gold (Au) relationships, Rabbit Creek, Alaska with other localities worldwide (from Naldrett and Cabri(2))

Locality	Pt/Pt + Pd (range of values)	Au/Pt + Pd + Au (range of values)
Rabbit Creek, Alaska	0.44 - 0.65	0.09 - 0.29
"Alpine Complexes"	0.62 - 0.91	0.022
"Alaskan-type Complexes"	0.60 - 0.89	0.015 - 0.0040
"Layered Complexes, Excluding Heavily Mineralized Zones"	0.29 - 0.69	0.017 - 0.037
"Nickel-Copper Sulfide Ores"	0.11 - 0.76	0.02 - 0.15

TABLE 4. - Comparison of Pt/Pt + Pd Ratios, Rabbit Creek, Alaska, and Selected Other Occurrences Worldwide, from Naldrett and Cabri (2)

Locality	Pt/Pt + Pd (range)
Rabbit Creek, Alaska	0.44 - 0.65
Layered Complexes, Excluding Heavily Mineralized Zones	
Stillwater Complex, Montana:	
Bronzitite Member	0.64
Upper Bronzitite	0.50
Banded and Upper Zone	0.69
Bushveld Complex, South Africa	
Potgietersrus	0.48
UG 2	0.55
Pseudo Reef	0.64
Main Magnetite	0.45
Nickel-Copper Sulfide Ores	
Sudbury, Ontario, Canada:	
Overall average	0.48 - 0.49
Pechenga (Petsamo), U.S.S.R.	0.55
Merensky Reef, Bushveld Complex, South Africa	0.70 - 0.72
Raglan, Quebec, Canada:	
Disseminated ore	0.40
Massive ore	0.76
Shangani, Rhodesia:	
Massive ore	0.39

The Au/Pt + Pd + Au ratios for the Rabbit Creek samples are compared with selected occurrences worldwide in table 5. The Pt/Pt + Pd ratios, as functions of the Au/Pt + Pd + Au ratios, for the Rabbit Creek samples and for relevant other occurrences worldwide are presented in figure 4.

There is a general clustering of three of the four data points representing Rabbit Creek samples (fig. 4). The fourth point is "anomalous" and may represent analytical and/or geological factors. In general, the plotted parameters of the Rabbit Creek samples lie in a relatively restricted field which is in close proximity to data points representing samples from Sudbury, Pechenga, and the Merensky Reef.

PETROGRAPHIC AND PETROLOGIC RELATIONSHIPS

Polished thin-sections and thin-sections of the Rabbit Creek samples were examined. Results of this work are summarized in table 6.

In general, the rocks are crudely- to well-layered, at the hand specimen scale, with zones of plagioclase feldspar (An_{60+}) alternating with zones in which mafic minerals and associated alteration products are concentrated. The textures are interpreted as igneous cumulates, with cumulus plagioclase, and irregular patches of presumably intercumulus ($\pm$ cumulus) mafic material. The latter are generally intensely altered to a complex suite of phases difficult to decipher optically. Primary olivine seems to have been ubiquitous in these patches, although its presence has since been reduced to mere relict/ghost status in some samples. Cumulus pyroxene was recognized in two of the samples studied. The rocks appear to have been subjected to, and modified by, moderate deformational stresses.

Based on bulk mineralogic composition and petrographic characteristics, these rocks are troctolites $\pm$ gabbros, with individual anorthosite

TABLE 5. - Comparison of Au/Pt + Pd + Au Ratios, Rabbit Creek, Alaska and Selected Other Occurences, Worldwide, from Naldrett and Cabri (2)

Locality	Au/Pt + Pd + Au (range)
Rabbit Creek, Alaska	0.09 - 0.29
Nickel-Copper Sulfide Ores	
Merensky Reef, Bushveld Complex, South Africa:	
Western Platinum Mine	0.06 - 0.08
Vlakfontein, South Africa:	
Discordant nickel sulfide pipes	0.15
Sudbury, Ontario, Canada:	
Overall average	0.15
Pechenga (Petsamo), U.S.S.R.	0.15
Marbridge, Quebec, Canada:	
Marbridge #1, concentrate, adjusted	0.12
Kanichee:	
Sulfide-rich ore	0.13
Average concentrates for 1974-75	0.18

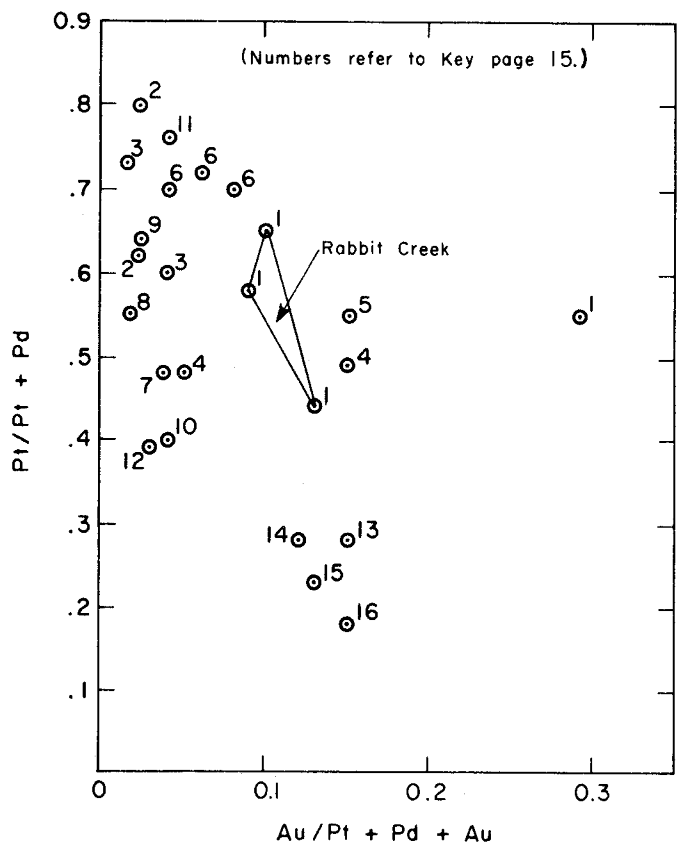

Figure 4.--Plot of the ratio Pt/Pd + Pd as a function of the ratio Au/Pt + Pd + Au for Rabbit Creek, Alaska, and selected other localities worldwide (from Naldrett and Cabri (2)).

Key to Numbers, Figure 4

Category and Locality	Key Number
Rabbit Creek, Alaska:	1
"Alpine Complexes":	
Urals, U.S.S.R. -	2
"Alaskan-Type Complexes":	
Urals, U.S.S.R. -	3
"Nickel-Copper Sulfide Ores":	
Sudbury, Ontario, Canada -	
Overall Average	4
Pechenga (Petsamo),	
U.S.S.R.	5
Merensky Reef, Bushveld Complex,	
South Africa -	6
Raglan, Quebec, Canada -	
Disseminated Ore	10
Massive Ore	11
Shangani, Rhodesia -	
Massive Ore	12
Vlakfontein, South Africa -	
Discordant Nickel - Sulfide pipes	13
Marbridge, Quebec, Canada -	
Marbridge #1, concentrate, adjusted	14
Kanichee -	
Sulfide-rich ore -	15
Average concentrates for 1974-75	16
"Layered Complexes, Excluding Heavily Mineralized Zones":	
Bushveld Complex, South Africa -	
Potgietersrus	7
UG 2	8
Pseudo Reef	9

(plagioclase-rich) and dunite-peridotite (mafic-rich) zones as petrographic "end-members". Due to strong alteration, the nature of much of the primary mafic phases(s) is now essentially indeterminate. Some of these primary mafic minerals may well originally have been pyroxene, thus necessitating reconsideration of petrologic designations (i.e. some of the "troctolite", might well have been a "gabbro" originally, etc.).

The more mafic zones appear to represent primary igneous olivine (± clinopyroxene) with associated reaction/alteration products such as pyroxene, amphibole(s), serpentine, and chlorite, together with a black opaque material (magnetite [?]) and possibly other optically indeterminate materials. There seems to be a distinct, but complex reaction/alteration zones ("corona") between the mafic minerals and plagioclase. Coronas such as this are not uncommon in troctolitic rocks elsewhere, and they frequently are involved in strongly altered zones within such rocks. Such alteration has been ascribed variously to deuteric and/or hydrothermal processes. The plagioclase in the Rabbit Creek samples frequently shows alteration to clinozoisite ± zoisite-epidote along the corona-bordering areas as well. There appears to be some concentration of sulfide phases associated with the more mafic zones, although the sulfides are disseminated fairly uniformly throughout the specimens studied, and are frequently intergranular to plagioclase in areas not obviously associated with mafic alteration.

The general impression is one of primary igneous segregation of plagioclase- and mafic-rich layers, with reaction relationships at the borders between the phases involved, with deuteric and/or later-stage hydrothermal alteration superimposed upon this. The magnetite appears to have developed as a consequence of the alteration of the previously existing mafics, while the sulfide minerals are somewhat indeterminate as to their paragenesis. The

TABLE 6. - Summary of Preliminary Petrographic Analyses of Selected Samples from Rabbit Creek, Alaska. (Petrologic classification follows Streckeisen (3))

77-87 Medium-grained troctolite/troctolitic anorthosite. Plagioclase (cumulus) An_{60+}, twinned, weakly zoned altered by reaction along grain margins adjacent to primary mafic minerals; layered-like zones/irregular patches of concentrations of olivine interstitial to plagioclase, contrasted with zones essentially free of mafic minerals; barely recognizable olivine relicts, surrounded by generally concentric zones of phases produced at least in part by the reaction relationship between olivine and adjacent plagioclase; these concentric zones have been at least partially altered (deuteric and/or hydrothermal?), and are presently constituted of recognizable amphibole, chlorite, magnetite, zoisite, ± serpentine, with complex interrelationships among these and possible other, unrecognized phases; the overall impression here is a situation of reaction between primary cumulus and intercumulus igneous phases, with subsequent (continuous?) deuteric and/or hydrothermal alteration, particularly affecting the mafic minerals; to some extent, the nature of this alteration seems to be a function of the presence or absence of adjacent plagioclase in any particular instance; the mafics have altered strongly and preferentially, while plagioclase only seems to have been affected along zones where mafics were altering, and where plagioclase adjoined such zones. Disseminated patches of sulfide phases occur, including occurrences of chalcopyrite interspersed particularly within the reaction/alteration zones described above. Additionally, somewhat larger (0.5 mm maximum observed) patches of chalcopyrite, complexly intergrown with bornite, and less frequently pyrrhotite, pyrite (± pentlandite?). The latter intergrowths appear to represent exsolution of these phases from a previously existing sulfide solid solution phase originally stable at a higher temperature (presumably the "iss" as discussed by Cabri (1), Vaughn and Craig (4)). Covellite is developed as an apparent further modification of bornite, in scattered occurrences. The sulfide phase relationships recognized are consistent with either a primary igneous or high temperature hydrothermal introduction origin for these materials, relative to their present host rocks. The sulfide phases seem to be spatially concentrated in the alteration zones, though by no means exclusively so. The sample is layered on the hand-specimen scale, with contrasting zones of inversely varying proportions of plagioclase and mafic minerals. Specimens of this sample were studied in polished thin-section.

77-109 Medium-grained troctolite. Plagioclase (cumulus?) An_{60+}, with intergranular (intercumulus?) olivine, strongly altered (in part reaction coronas adjacent to plagioclase); minor clinopyroxene, amphibole; alteration materials include serpentine, chlorite, black opaque phases, epidote; the plagioclase and mafic-rich areas are approximately subequal in this specimen; the rock has been moderately-severely affected by deformational stresses. This specimen was examined only in standard thin-section, hence meaningful characterization of opaque phases, including sulfides, is not feasible at this time. Sulfide phases are disseminated throughout the specimens studied, in apparent (primary igneous?) intergranular textural relationships with the plagioclase as well as the altered mafic minerals. On the hand specimen scale, the sample is layered, with contrasting zones with inversely varying proportions of plagioclase and mafic minerals.

TABLE 6. - Summary of Preliminary Petrographic Analyses of Selected Samples from Rabbit Creek, Alaska. (Petrologic classification follows Streckeisen (3))-- Continued

J77-112 Medium grained olivine-gabbro/leuco-troctolite. The sample is layered on the hand-specimen scale, with contrasting zones of inversely varying proportions of plagioclase (cumulus) and mafic minerals. In the gabbroic portion of the sample, plagioclase is An_{65+}, slightly bent and strained. Mafic (cumulus and intercumulus) minerals are clinopyroxene, orthopyroxene, and olivine, with patches and poikilitic areas of pleochroic amphibole. If the amphibole is considered as a primary igneous crystallization phase (?), there is little apparent alteration of the mafic minerals in this specimen. Some chlorite is recognizable, and opaque phases, with slight development of serpentine were also discernible throughout the zones of mafic mineral concentration. The specimens were examined only in standard thin-section, hence definitive characterization of opaque phases was not feasible. The sample appears to have been subjected to only relatively slight deformational stress, although this is somewhat questionable in that stress relief in the rocks may have taken place within the finer-grained mafic-rich zones.

In the leuco-troctolitic portion of the sample, the plagioclase (cumulus) is An_{65+}. The primary (intercumulus?) igneous mafic minerals (olivine ± pyroxene?) are very strongly altered to a complex composite of phases, of which chlorite and serpentine are recognizable. There is a decided reaction corona developed along the plagioclase grains where they lie adjacent to the mafic materials, reminiscent of the relationships described in sample J77-87. Patches of sulfides (0.4 mm maximum size) are disseminated throughout the specimen studied, intergranular to the plagioclase as well as the altered mafic materials. This portion of sample J77-112 seems quite similar to sample J77-87.

J77-128 Medium-grained olivine gabbro. Mafic minerals (cumulus ± intercumulus) include clinopyroxene, olivine, and perhaps some minor orthopyroxene, slightly - moderately altered to serpentine, chlorite and black opaque phases; plagioclase (cumulus) is An_{60+}. Fractures which traverse the specimen studied are accompanied by alteration of mafic minerals and plagioclase quite similar to the "corona" relationships described between plagioclase and mafic minerals in samples J77-87, 109, 112, and 140. This might indicate that late stage deuteric and/or hydrothermal alteration precesses were, in fact, responsible for these "corona-like" relationships, but clarification of this situation will require more detailed study. The alteration in the particular specimen examined is definitely fracture-controlled, and the spectrum of serpentine - chlorite - black opaque phases - zoisite/clinozoisite - eipdote alteration products is well developed. Perhaps significantly, in this gabbroic rock, there are no recognizable sulfide phases associated with either the primary igneous minerals or the alteration materials. The specimen was only studied in standard thin section.

TABLE 6. - Summary of Preliminary Petrographic Analyses of Selected Samples from Rabbit Creek, Alaska. (Petrologic classification follows Streckeisen (3))-- Continued

J77-140 Troctolite-gabbro (?), medium-grained. Plagioclase (cumulus) An_{60+}; irregular patches (intercumulus) of strongly altered mafics, with excellent development of the "corona" sequence pyroxene (?) - black opaque phases - amphibole - chlorite - zoisite/clinozoisite - epidote from relict primary mafics (apparently principally olivine) to altered plagioclase, with optically indeterminate elongate very fine lath-like materials making up the bulk of the most intensely altered mafic zones. Sulfide patches (0.6 mm maximum) are disseminated throughout the specimen, intergranular both to plagioclase and altered mafic materials.

This specimen is quite similar in overall aspect to J77-87 and 112. This sample was studied in standard thin-section only, hence further characterization of the opaque phases is not feasible at this time.

J77-150 Troctolite-gabbro (?), medium-grained. Plagioclase (cumulus) An_{60+}, irregular patches (intercumulus) of primary igneous mafics very strongly altered, with only hints of relict (olivine) material; the alteration sequence pyroxene(?) - black opaque phases - amphibole - chlorite - zoisite/clinozoisite - epidote, from relict core to adjacent altering plagioclase, is well developed; sulfide patches (0.4 mm maximum size) are scattered as intergranular disseminations to plagioclase and altered mafic zones, throughout the specimen. The rock has been moderately affected by deformational stresses, with numerous through-going fractures, along which alteration has taken place.

The specimen was examined in standard thin-section only, hence characterization of opaque phases was not attempted.

magnetite is cut by chalcopyrite in some areas, indicating later introduction and/or mobilization of the sulfides, at least in part, subsequent to alteration of the mafic minerals. Much of the chalcopyrite is intimately associated with the bornite, pyrrhotite and pyrite (± pentlandite?), in apparent mutual exsolution relationships. Areas in which chalcopyrite-bornite-pyrrhotite, or chalcopyrite-bornite-pyrrhotite (± pentlandite?) are in mutual grain-boundary contact with one another are discernible. This suggests exsolution from a higher temperature sulfide phase (1), attendant upon cooling. This in turn, tentatively might be interpreted as indicating that the sulfide phase(s) are also of primary igneous origin, and were not introduced subsequently. At least these sulfides would have had to have been introduced at somewhat elevated temperatures if this tentative interpretation is correct (4). Textural relationships among the silicate, sulfide, and oxide phases present, although not unambigous, also tend to support this. Occasional occurrences of covellite associated with bornite suggest subsequent alteration/modification of the latter, at yet lower temperatures.

RELATIONSHIP OF PGE TO MINERALOGY

Several possibilities exist with respect to the manner in which the reported PGE values might occur within the Rabbit Creek samples. Within the limits of resolution of the optical microscope, no entities which could be identified unequivocally as discrete phases consisting of PGE in major proportions have been recognized. The PGE might be anticipated to occur intimately associated with the sulfide phases present in these samples. Chemical and mineralogic data appear to support such a mode of occurrence (table 1, fig. 3). The sulfides recognized are predominantly chalcopyrite and bornite, with lesser pyrrhotite and pyrite (± pentlandite?). Covellite is associated with the bornite in some areas, apparently as an alteration/modification product of bornite. Association of PGE in the form of alloys , arsenides, sulfarsenides, bismuth- and antimony-bearing phases, and tellurides in association with copper and/or nickel sulfide ores is common geochemically, in other reported occurrences elsewhere.

The textural and distributional relationships suggest that much of the sulfide material may have been present at the magmatic stage, perhaps evolving to and through an immiscible sulfide melt phase(s) during the course of petrogenetic events. However, there are also indications of some sort of late-stage concentration and/or introduction of deuteric/hydrothermal fluids, with resultant alteration of pre-existing igneous mafic minerals, particularly in zones where these mafic minerals occur adjacent to primary igneous plagioclase. In the latter zones, reaction relationships between primary igneous phases seem to have provided regions in which subsequent alteration (± attendant mineralization with sulfides ± PGE ?) was enabled to proceed more readily.

Remobilization may be the cause of the observed paragentic sequences which indicate that at least some of the chalcopyrite transects and, hence, was emplaced subsequent to previously existing magnetite. Similar relationships would explain the observed intimate intergrowths of sulfide material with the other mafic alteration products as well.

CONCLUSIONS

Mafic and ultramafic rocks found as cobbles along Rabbit Creek contain high Pt and Pd values. Higher Pt and Pd values correlate with zones of high Cu and visible sulfides. The bedrock sources of these is not known but mafic/ultramafic rocks are present in the region.

The large volume of such rocks recognized across much of the northwestern Alaska region, together with their general petrologic characteristics, seem to represent sufficient justification for further investigations.

The extremely small relative dimensions of known significant concentrations of PGE worldwide necessitates painstakingly detailed field and laboratory work in the search for analogous presently undetected concentrations. The search can be narrowed considerably by focusing on rocks of appropriate character, such as at least some of these known to exist across northwestern Alaska.

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