RECONNAISSANCE STRATEGIC AND CRITICAL MINERAL INVESTIGATIONS IN THE
MCGRATH A-3 AND B-2 QUADRANGLES, SOUTHWEST ALASKA

By Jeffrey Y. Foley

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UNITED STATES DEPARTMENT OF THE INTERIOR
Donald Paul Hodel, Secretary

BUREAU OF MINES
David S. Brown, Acting Director
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INTRODUCTION

The Bureau of Mines Alaska Field Operations Center (AFOC) has, since 1981, been investigating reported platinum-group metal (PGM) and cobalt occurrences in Alaska. These investigations are being conducted as part of AFOC's strategic and critical minerals program which includes past and present statewide assessments of minerals that are essential to the nation's defense and industrial well-being; minerals investigated to date include PGM, cobalt, chromium, tin, tantalum, columbium, and rare-earth elements. The results of AFOC's critical and strategic mineral investigations are presented in Bureau publications, open-file reports, unpublished field reports, and outside publications. This report summarizes the Bureau's investigation of selected cobalt, PGM, and other mineral occurrences in 1985, near Farewell, in the USGS McGrath Quadrangle, southwest Alaska (fig. 1). The results of this report and others on cobalt and PGM will, in the future, be included in statewide summary reports for the respective commodities.

GEOLOGY

Rocks in the Farewell area are separated into two lithologically and structurally distinct sequences by the Farewell fault. This fault is the southwestern extension of the Denali-Shakwak fault system and is characterized by 40 mi right-lateral Cenozoic displacement; vertical movement also occurred during the Cenozoic, and Quaternary movement has been entirely vertical, with the southern block uplifted (Bundtzen, Kline, and Clough, 1982 and Bundtzen and Gilbert, 1983).
FIGURE 1.- Location map.
North and west of the Farewell fault is a sequence of relatively undeformed, shallow-water sedimentary rocks that are interpreted by Bundtzen and Gilbert (1983) to represent carbonate platform deposits. Immediately north of the Farewell fault, are massive, and locally laminated, Middle to Late Devonian limestones with minor interlayered sandstone (Bundtzen, Kline, and Clough, 1982). These rocks are overlain by Paleozoic to Mesozoic mafic igneous rocks, chert, and conglomerate. The mafic igneous rocks and associated chert are similar to the Silurian Chilakadrotna Greenstone, north of Lake Clark, Paleozoic to Triassic rocks of the Gemuk Group, exposed throughout southwest Alaska, and parts of the Mississippian Innoko Terrane in the USGS Medfra and Ophir Quadrangles (Bundtzen, Kline, and Clough, 1982). The rocks north of the Farewell Fault are provisionally assigned to the Nixon Fork tectonostratigraphic terrane which underlies much of the Medfra Quadrangle to the north.

To the south of the Farewell fault, Ordovician and Silurian deep-water sediments of the Dillinger tectonostratigraphic terrane are overlain by shallow-water Devonian sediments (Bundtzen, Kline, and Clough, 1982). This entire sequence increases in age to the south, and together, the rocks are folded and overturned into northwest-verging nappes (Solie, 1982).

The Ordovician rocks include shale and siltstone that grade upward into darker gray shale, black chert, and thin volcaniclastic sand layers. This sequence is interpreted by Bundtzen and others (1982) to represent initial quiescent, deep-water sediments, that were deposited on an abyssal plain or continental margin.
The Silurian sequence contains rhythmically-layered sandstone, silstone, laminated limestone, and shale that grade upward into fine-grained siltstone and shale (Bundtzen, Kline, and Clough, 1982). This clastic sequence includes Bouma intervals and other sedimentary features indicative of turbidity currents and turbidite deposition (Bundtzen, Kline, and Clough, 1982).

A thick sequence of undated, laminated limestone, dolomitic limestone, calc-sandstone, shale, and minor chert and volcanogenic (?) sedimentary rocks overlies the Silurian sequence (Bundtzen, Kline, and Clough, 1982). This sequence contains sedimentary structures that indicate a depositional environment similar to that interpreted for the Silurian sequence (Bundtzen, Kline, and Clough, 1982).

The stratigraphically highest Paleozoic sequence, south of the Farewell fault, contains algal limestone, shale, chert, mafic and ultramafic flows, sills, and dikes, and a late Middle Devonian clastic chert sequence (Bundtzen, Kline, and Clough, 1982). The sedimentary environments and the presence of chert, and ultramafic to tholeiitic mafic igneous rocks in shale and sandstone intervals indicates an ocean-floor environment.

The area is intruded by a variety of igneous rocks ranging in age from Late Cretaceous to Oligocene (Bundtzen, Kline, and Clough, 1982 and Solie, 1983). Igneous rocks in the area comprise dike swarms, flows, sills, breccia pipes, and small stocks of dominately intermediate composition, with alkaline mafic components. Subparallel dike swarms include basaltic through rhyolitic composition. The dikes resemble and may be genetically analogous to dike swarms described in the eastern Alaska Range (Foley, 1982, 1984, and 1985). Bundtzen and
others (1982) suggest that dike swarms like those in the vicinity of the dumbell-shaped intrusion near the Rat Fork prospect may represent the root zones of volcanic centers.

Two major volcanic complexes in the area are described by Bundtzen and others (1982). One of these caps a ridge, west of Veleska Lake, and the other overlies Middle Devonian layered rocks, west and north of Sheep Creek. The Veleska Lake complex ranges from basalt to rhyolite in composition but comprises mostly dacite. The Veleska Lake complex is intruded by Paleocene granodiorite and dacite dikes and sills that resemble the flow rocks of the complex (Bundtzen, Kline, and Clough, 1982). The Sheep Creek complex postdates most of the Paleocene intrusive rocks and is composed of basalt, andesite, and rhyolite-welded (?) tuffs that are overlain by graded airfall tuffs.

Solie (1983) has described, in detail, the Middle Fork plutonic complex, which underlies the southern portion of the McGrath A-3 Quadrangle. That complex comprises granite, quartz monzonite, monzodiorite, syenite, and alkali gabbro and is believed to be part of the late Cretaceous through Tertiary suite of igneous plutons in the much larger Alaska-Aleutian Batholith (Solie, 1983).

Overlying the Paleozoic and Mesozoic rocks in the southeastern McGrath Quadrangle are extensive alluvial and colluvial deposits. Alluvial deposits include extensive gravel deposits, particularly on the piedmont, north of the Farewell fault (Bundtzen, Kline, and Clough, 1982) and in the larger valleys south of the fault. These gravel deposits include glacial drift and extensive terrace deposits. Overlying the gravel deposits, north of the fault, are extensive,
permanently frozen, organic-rich, silt deposits. Colluvial cover is abundant on the flanks of the mountains in the southern part of the study area and landslide deposits are locally present. Periglacial phenomenon, such as solifluction and aufeising, are common in the higher areas. Some glacial ice remains in cirques and alpine valleys at higher elevations.

MINERAL OCCURRENCES AND AREAS INVESTIGATED

The areas examined during this investigation are shown on figure 2; also shown are known prospects in the region. See Bundtzen and Gilbert (1983) and Smith and Albanese (1985) for descriptions of the known prospects.

Chip Loy Prospect

The Chip Loy prospect is named after its discoverers, Ed Chip and Robert Loy. The deposit is located on the east side of a north-flowing tributary of the the Middle Fork of the Kuskokwim River (fig. 2). The north-flowing tributary was informally named Straight Creek by Gordon Herreid, who described the prospect during a geological and geochemical survey of the area in 1966 (Herreid, 1968). The deposit was later sampled by the Bureau of Mines in 1981 (Roberts, 1985), during an examination of prospects in the area by the Alaska Division of Geological and Geophysical Surveys (Smith, and Albanese, 1985), and during the present investigation.

The Chip Loy prospect crops out between the 2,900- and 4,000-ft elevations in a steep, west-facing cliff and contains disseminated and massive pyrrhotite along the contact of a steeply-dipping diabase mass that has intruded banded limestone and slate (Herreid, 1968 and Smith and Albanese, 1985). The diabase mass was described by Herreid (1968)
FIGURE 2.- Prospects and areas investigated in the southeastern McGrath Quadrangle.
as a pipe(?) and by Smith and Albanese (1985) as a dike(?). The diabase body is elongate to the northeast, generally conforming to the layering in the sedimentary country rock and has an irregular width and outline, with shoots obliquely cutting the country rock. Pyrrhotite, the most abundant sulfide mineral, is present as disseminated grains, blebs, and aggregates, irregular veins, and as massive segregations. Polycrystalline pyrrhotite masses locally contain pyrrhotite crystals up to 2 in across. Pyrite, the second most abundant sulfide mineral, occurs along pyrrhotite grain boundaries, as disseminated grains and aggregates, and as flames in pyrrhotite. Chalcopyrite is locally present as a minor constituent along grain boundaries and fractures in pyrrhotite-pyrite aggregates. As observed at the surface, throughout and on either side of the mineralized area, the sulfide-rich rock is stained a deep, brick-red color with goethite and other oxides coating the weathered rock. James Sjoberg, Bureau of Mines Mineralogist at Reno (NV) Research Center, observed bravoite (violarite), pyrite, chalcopyrite, magnetite, hematite, and trace galena during scanning-electron microscope examination of pyrrhotite-rich rock collected by William Roberts from the Chip Loy prospect. No pentlandite was observed and it was concluded that nickel and cobalt are present in bravoite which, along with carrolite and violarite, is in the linnaeite [(Co,Ni)S] mineral group.

According to Smith and Albanese (1985), from 0.25 million to 2.0 million short tons of sulfide-bearing material may exist at the Chip Loy prospect. Based on reported analyses (table 1), grades ranging from 0.05 to 0.5 pct copper, 0.1 to 1.0 pct nickel, 0.02 to 0.1 pct Co, and trace gold and silver might be expected to be recovered from the Chip Loy prospect.
Table 1. - Analytical results and descriptions of Chip Loy prospect and Straight Creek samples.

Analytical results

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<tr>
<th>Sample</th>
<th>Ag, ppm</th>
<th>As, ppm</th>
<th>Au, ppm</th>
<th>Co, ppm</th>
<th>Cu, ppm</th>
<th>Fe, pct</th>
<th>Ni, ppm</th>
<th>Pd, ppm</th>
<th>Pb, ppm</th>
<th>Pt, ppm</th>
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<td>3.91</td>
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<td>NA</td>
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KW19457 1 NA <.1 NA 50 NA 150 NA NA NA

KW19458 1 NA NA NA 500 NA 57 NA

KW19459 1 NA NA NA 860 11,500 NA 8,000 NA 57 NA

KW19460 1 NA NA NA 1,050 700 NA 11,500 NA 29 NA

KW19460 2 NA NA NA <0.0002 NA NA NA NA <0.001 NA <0.001

KW19460 3 NA NA NA 595 970 NA >25,000 NA NA NA

KW24527 2 7.2 NA NA NA 1,800 1,400 NA 26,000 NA 110 NA

KW24530 2 2.6 NA NA NA 0.97 77 710 NA 1,200 NA <10 NA

KW24531 2 6.1 NA NA NA 0.003 2,500 10,000 NA 33,000 NA 110 NA

KW24532 2 13.5 NA NA NA 0.002 640 21,000 NA 8,500 NA <10 NA

KW24560 2 NA NA NA 0.001 270 95 NA 72 <0.0003 <10 <0.0003


1 Atomic absorption analyses by Technical Services Laboratories, Spokane, WA.
2 Inductively coupled-plasma analyses by Bureau of Mines Reno Research Center: Ag, Au, Pd, and Pt preconcentrated by fire-assay.
3 Atomic absorption analyses by Bondar-Clegg, Inc., Lakewood, CO; Au, Pd, and Pt preconcentrated by fire-assay.

Descriptions

KW19457 Stream sediment sample from Straight Creek.
KW19458 Goethite gossan.
KW19459 Massive pyrrhotite with minor chalcopyrite.
KW19460 Massive pyrrhotite.
KW24527 Massive pyrrhotite with minor chalcopyrite.
KW24530 Diabase with disseminated pyrrhotite and chalcopyrite.
KW24531 Very coarse-grained, massive pyrrhotite with chalcopyrite stringers.
KW24532 Chalcopyrite-rich massive and semi-massive pyrrhotite in fine-grained diabase.
KW24560 Pan-concentrated heavy mineral concentrate from Straight Creek (also contains 430 ppm Nb).
A 25-lb sample of pyrrhotite-rich rock was collected at sample location KW24527. This sample was crushed and blended at the Bureau's Albany (OR) Research Center and splits taken for head analyses by the Bureau's Reno Research Center and Bondar-Clegg, Inc., Lakewood, CO. Results of those analyses are listed in table 2.

Table 2. - Head analyses from high-grade Chip Loy sulfide sample (KW24527)

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<tr>
<th></th>
<th>Ag</th>
<th>Au</th>
<th>Co</th>
<th>Cu</th>
<th>Fe</th>
<th>Ni</th>
<th>Pb</th>
<th>Pd</th>
<th>Pt</th>
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<tbody>
<tr>
<td></td>
<td>ppm</td>
<td>ppb</td>
<td>ppm</td>
<td>ppm</td>
<td>pct</td>
<td>pct</td>
<td>ppm</td>
<td>ppb</td>
<td>ppb</td>
<td>pct</td>
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<td>4,100</td>
<td>43.1</td>
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<td>&lt;10</td>
<td>&lt;10</td>
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<tr>
<td>2</td>
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<td>5,000</td>
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<td>&gt;2.00</td>
<td>27</td>
<td>10</td>
<td>&lt;15</td>
<td>NA</td>
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1 Inductively-coupled plasma analyses by Reno Research Center. Au, Pd, and Pt preconcentrated by fire-assay.

2 Atomic absorption analyses by Bondar-Clegg, Inc. Ag, Au, Pd, and Pt preconcentrated by fire-assay.
Robert's PGM Occurrence

A mafic dike strikes northeast and cuts phyllite, siliceous mudstone and limestone at the crest of a northwest-striking ridge, 1.5 mi west of Straight Creek (figs. 2 and 4). The dike is sheared, shattered, serpentenized, and heavily-stained with iron oxide. Malachite and minor azurite locally coat the weathered rock and are concentrated along fractures. The rock contains pods and stringers of sulfide minerals including abundant pyrrhotite, with minor chalcopyrite and traces of sphalerite. The sulfide-bearing, iron-stained outcrop is about 20 ft by 60 ft in areal extent and is bounded by faulted intrusive contacts at its northeast and southeast margins. Sulfide minerals are most abundant along the contacts between the dike and the country rock and may represent skarn mineralization. Undulating shear surfaces throughout the exposed mass have slickensides on them and the mass may have been mostly crystallized upon emplacement into its present position.

Roberts reported anomalous copper, nickel, platinum, and palladium in sulfide-bearing pyroxenite and peridotite from this location in 1982, and samples collected during the present investigation confirmed the presence of those metals. Significant gold was also detected in the samples collected during the present investigation. Analytical results for samples collected by Roberts and during the present investigation are presented in table 3.

A 11.8-lb sample of pyrrhotite- and chalcopyrite-rich material was collected from Robert's PGM occurrence and forwarded to ALRC for mineralogical characterization, head analyses, and concentration of sulfide minerals by flotation. Results of those tests are not yet available.
FIGURE 4. - Robert's PGM occurrence (base map from McGrath A-3 Quadrangle).
Table 3. - Analytical results and descriptions of samples from Robert's PGM occurrence and adjacent area

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ag, oz/st</th>
<th>Au, oz/st</th>
<th>Co, ppm</th>
<th>Cu, ppm</th>
<th>Ni, ppm</th>
<th>Pb, ppm</th>
<th>Pd, oz/st</th>
<th>Pt, ppm</th>
<th>Zn, ppm</th>
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<td>KW19451</td>
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<td>140 3,100</td>
<td>5,330</td>
<td>NA</td>
<td>0.011</td>
<td>0.009</td>
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<td>81</td>
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<tr>
<td>KW19453</td>
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<td>67 435</td>
<td>1,565</td>
<td>NA</td>
<td>.001 &lt;.001</td>
<td>NA</td>
<td>&lt;.001 &lt;.001</td>
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</tr>
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1 Atomic absorption analyses for Co, Cu, and Ni by Bondar-Clegg, Inc. and Au, Pd, and Pt by Reno Research Center using inductively-coupled plasma procedures after fire-assay preconcentration.
2 Atomic absorption analyses by Technical Services Laboratories, Spokane, WA.
3 Inductively-coupled plasma analyses by Reno Research Center. Au, Pd, and Pt preconcentrated by fire-assay.
NA- Not analyzed
LD- Less than detection limit.

Descriptions

KW19451 Oxidized, sheared, blocky pyroxenite with pyrrhotite, pyrite, and trace chalcopyrite collected by Roberts.
KW19453 Very coarse-grained peridotite float with pyrrhotite and slickensides collected by Roberts.
KW19454 Sheared serpentinite collected by Roberts.
KW19455 Biotite pyroxenite collected by Roberts
KW19456 Carbonate vein collected by Roberts
KW24524 Random chip sample collected during present investigation over entire mineralized outcrop.
KW24525 High-graded Pyrrhotite-chalcopyrite rock collected during present investigation from mineralized contact.

Serpentenized mafic and ultramafic rock with associated sulfide minerals like those described here were not observed anywhere else in the immediate vicinity of Robert's occurrence. Coarse-grained pyroxenite, locally cut by carbonate veins was observed by Roberts about 2.5 mi south of the present occurrence, at sample locations KW19455 and KW19456 (fig. 4). No sulfide minerals or anomalous metal concentrations were detected in these two samples (table 3).
Table 3. - Analytical results and descriptions of samples from Robert's PGM occurrence and adjacent area

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ag, oz/st</th>
<th>Au, oz/st</th>
<th>Co, ppm</th>
<th>Cu, ppm</th>
<th>Ni, ppm</th>
<th>Pb, ppm</th>
<th>Pd, oz/st</th>
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<th>Zn, ppm</th>
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<td>KW19451</td>
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<td>&lt;0.0002</td>
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1 Atomic absorption analyses for Co, Cu, and Ni by Bondar-Clegg, Inc. and Au, Pd, and Pt by Reno Research Center using inductively-coupled plasma procedures after fire-assay preconcentration.
2 Atomic absorption analyses by Technical Services Laboratories, Spokane, WA.
3 Inductively-coupled plasma analyses by Reno Research Center. Au, Pd, and Pt preconcentrated by fire-assay.
NA- Not analyzed
LD- Less than detection limit.

**Descriptions**

KW19451 Oxidized, sheared, blocky pyroxenite with pyrrhotite, pyrite, and trace chalcopyrite collected by Roberts.
KW19453 Very coarse-grained peridotite float with pyrrhotite and slickensides collected by Roberts.
KW19454 Sheared serpentinite collected by Roberts.
KW19455 Biotite pyroxenite collected by Roberts
KW19456 Carbonate vein collected by Roberts
KW24524 Random chip sample collected during present investigation over entire mineralized outcrop.
KW24525 High-graded Pyrrhotite-chalcopyrite rock collected during present investigation from mineralized contact.

Serpentenized mafic and ultramafic rock with associated sulfide minerals like those described here were not observed anywhere else in the immediate vicinity of Robert's occurrence. Coarse-grained pyroxenite, locally cut by carbonate veins was observed by Roberts about 2.5 mi south of the present occurrence, at sample locations KW19455 and KW19456 (fig. 4). No sulfide minerals or anomalous metal concentrations were detected in these two samples (table 3).
Mafic and Ultramafic Sills, Flows, and Dikes

Mafic to ultramafic sills, flows, and dikes cap ridges and are intruded into late Middle Devonian siltstone, shale, and chert in the west-central portion of the McGrath B-2 Quadrangle (Bundtzen, Kline, and Clough, 1982). As described by Bundtzen and others (1982), these rocks include dark green to gray, fine- to coarse-grained, equigranular gabbro to diorite sills, gabbro and basalt dikes, and sheared pillow(?) basalt with minor chert confined to, and generally parallel to the underlying and enclosing sedimentary rocks. Up to 50 pct magnetite and up to 25 pct olivine are reported in the sills which are differentiated, with gabbro and ultramafic basal zones that grade upward into dioritic rocks. Bundtzen and others (1982) also report that cumulate fabrics were observed in olivine- and pyroxene-bearing rocks from these igneous bodies.

Mafic volcanic rocks of this group were examined in the Sheep Creek area during the present investigation (fig. 5) and sampled rocks are tentatively classified on the basis of hand specimen descriptions as basalt and basaltic-andesite. Associated rocks include dacite, rhyodacite, and rhyolite. In places, the mafic flow rocks are nearly 1,000 ft thick and have chilled contacts. Samples containing trace to accessory sulfide minerals, including pyrite, pyrrhotite, and chalcopyrite were collected for geochemical analyses and results and descriptions of those samples are listed in table 4. It was observed during this investigation that the mafic rocks are typically fine- to medium-grained phaneritic with a high color index (\(> 70\)) and containing about 20 pct interstitial plagioclase that is altered to a bluish-green colored mineral, probably epidote. Although these rocks are not strongly magnetic, very fine-grained, disseminated magnetite grains
FIGURE 5. - Mafic and ultramafic flows, sills, and dikes, Badnews skarn, and pyrrhotite occurrence (base map from McGrath B-2 Quadrangle).
Table 4. - Analytical Results and Descriptions of Mafic, Ultramafic and associated rocks.

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<th>Nb, ppm</th>
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1 Inductively-coupled analyses by Reno Research Center; Ag, Au, Pd, and Pt preconcentrated by fire-assay.
LD- Less than detection limit.

Descriptions

KW24544 Fine-grained mafic dike with very fine, disseminated pyrite.
KW24545 Do.
KW24546 Phaneritic, blue-green basaltic andesite with accessory magnetite and very fine-grained sulfide minerals.
KW24547 Dark blue-green phaneritic basaltic andesite with 5 pct 4 to 6-mm hornblende phenocrysts and accessory pyrite and chalcopyrite.
KW24548 Buff-colored silica-carbonate-altered basaltic andesite.
KW24549 Dark black mafic basalt with blue-green, interstitial, epidotized plagioclase.
KW24551 Blue-green, phaneritic, sub-ophitic basalt with accessory chalcopyrite.
KW24552 Fine-grained phaneritic basalt with accessory pyrite.
KW24553 Pink to buff-weathering silica-carbonate-altered basalt.
KW24554 Medium-grained phaneritic basalt with blue-green interstitial feldspar.
KW24555 Medium-grained basaltic andesite with blue-green interstitial feldspar and accessory pyrite.
KW24556 Fine-grained, blue-green basaltic andesite with accessory sulfide minerals.
KW24557 Pink-weathering, pyrite-bearing, ankeritic quartzite.
KW24558 Dark brown, fine-grained, phaneritic basalt.
are typically present and fine-grained sulfide minerals, although ubiquitous, are not very abundant and generally constitute less than .5 pct of the rock. Other than traces of silver and gold, both near the lower detection limits for those metals, no anomalous metal concentrations were detected in any of the analyzed rocks.

A swarm of pyrrhotite-bearing mafic dikes was also observed in the southeast corner of section 20 and in the northwest corner of section 28, T23N, R26W, McGrath A-3 Quadrangle (fig. 6). Samples KW24544 and KW24545 from this area contained no anomalous metal concentrations (table 4).
FIGURE 6. - Pyrrhotite-bearing mafic dikes and reported eudialyte location (base map from McGrath B-2 Quadrangle).
Badnews Skarn Prospect

The Badnews prospect, named by R. Burleigh during mineral investigations conducted in 1979 by Placid Oil Co., is a Cu-Pb-Zn skarn deposit in tightly-folded limestone, siltstone, and argillite (fig. 5). Limestone at the prospect has been preferentially replaced by skarn minerals, whereas, the siltstone and argillite are hornfelsed and bleached to light purplish-green and off-white colors. East-northeast-striking dacite dikes intrude the limestone in the area. Locally, the siltstone and argillite contain sulfide and calcite veins proximal to dacite dikes and massive skarn in limestone. It is suggested on the basis of field observations that later, and possibly related, hydrothermal fluids altered the dacite dikes and concentrated the skarn-forming metals. A post-skarn breccia occurs at the contact of a dacite dike in limestone and as breccia veins that cross-cut relatively fresh limestone. Late quartz-calcite veins that contain coarse-grained pyrrhotite-chalcopyrite-sphalerite-galena aggregates that parallel the dike and cleavage surfaces in the enclosing rock are up to 2 ft wide. By contrast, pyrrhotite-rich masses that contain little of the other sulfide minerals are up to 6 ft wide. Skarn mineralization in the limestone is varied in appearance. A buff-colored alteration assemblage is often observed in strata that are bounded above and below by relatively unaltered gray limestone. The buff-colored rock commonly grades into dark green to brownish-green rock characterized by the presence of epidote, garnet, fine-grained biotite and amphibole. Copper-, lead-, and zinc-sulfide mineral abundance is greatest in the darker-colored rock but chalcopyrite is locally present in the massive
pyrrhotite pods. Also observed at this prospect is magnetite-garnet
assemblage in fine-grained, yellow-green, calcite-garnet rock.

Table 5. - Analytical results and descriptions of samples
from the Badnews skarn prospect.¹

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¹ Inductively-coupled plasma analyses by Reno Research Center; Ag and
Au preconcentrated by fire assay.

Descriptions
KW24556 Massive pyrrhotite with minor chalcopyrite and trace
sphalerite.
KW24580 Pyrrhotite, chalcopyrite, and sphalerite in dark-green skarn
assemblage.

Pyrrhotite Occurrence

One mile southwest of the Badnews skarn prospect (fig. 6), massive
pyrrhotite is reported by Bundtzen (1985). This location was examined
during the present investigation and pyrrhotite, along with pyrite, was
found to occur in carbonate-altered andesite dikes that cut the lime-
stone country rock. The sulfide minerals are widely distributed as very
fine-grained, disseminated grains and less frequently are observed in
fine veinlets and coarse clots and crystals up to 1 in across. Also
observed in the area were a 20-ft-wide granodiorite dike and a small
plug of dacite porphyry. Sample analyses and descriptions from this
area are listed in table 6.
Table 6. - Analytical results and descriptions of pyrrhotite samples

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1 Inductively-coupled analyses by Reno Research Center; Ag, Au, Pd, and Pt preconcentrated by fire-assay.

Descriptions

KW24566  Carbonate-altered andesite with disseminated pyrrhotite and trace chalcopyrite.
KW24567  Do.
KW24568  Dark gray massive limestone with coarse pyrrhotite aggregate.
KW24569  Pyritic, gray limestone.
KW24571  Carbonate-altered hornfels with disseminated pyrrotite.
KW24572  Gray-green pyrrhotite-bearing volcanioclastic rock cut by calcite veins.

Eudialyte Occurrence

Eudialyte is reported by Gilbert and Solie (1983) and Bundtzen (1985) to occur in peralkaline arfvedsonite granite of the Windy Fork pluton in the southeast quarter of section 28, T23N, R26W, McGrath A-3 Quadrangle (fig. 6). A brief search for the reported occurrence was unsuccessful.
Tertiary Dikes

Near-vertical Tertiary dikes, showing a wide range of compositions, occur throughout the southeastern McGrath Quadrangle and are locally sheeted, constituting up to 50 pct of outcrops. The dikes range in composition from basaltic to rhyolitic, with abundant intermediate compositions. East-west strikes are typical among these dikes which appear to have intruded the older rocks in response to regional stresses that resulted in planes of weakness that parallel are slightly oblique to the northeast-striking Farewell fault. It is noteworthy that the compositional variation among the dikes, their structural style of emplacement, and the presence of ocellar and amygdaloidal textures are strikingly similar to features that characterize two suites of alkaline mafic and ultramafic rocks described in the eastern Alaska Range (Foley, 1982, 1984, and 1985). In those cases, the presence of widely-varied compositions, and more specifically, the presence of both alkaline and subalkaline compositions, was attributed to crustal contamination of varied magmas that originated within an heterogeneous mantle and were emplaced at shallow depths in the crust as result of deep-seated faults that propagated along the Denali and Farewell faults (Foley, 1985). Furthermore, available radiometric age dates indicate that all these dikes were emplaced at progressively younger times going from east to west along the Denali fault.

Summaries of petrographic descriptions of dikes in the McGrath B-2 and A-3 Quadrangles are provided by Bundtzen and others (1982) and Gilbert and Solie (1983).

During the present investigation, six samples of pyritic rhyolite and rhyodacite dikes were collected along the north-south-striking
ridge in sections 18 and 19, T24N, R26W, McGrath A-3 Quadrangle. Fire-assay atomic absorption analyses detected no gold in five of the samples and only 9 ppb in a sixth sample from a 60-ft-wide rhyolite dike.

Bundtzen and others (1982) note that contact mineralization and thermal effects are generally lacking proximal to these dikes. Near the Veleska Lake and Sheep Creek areas, however, contact and breccia pipe mineralization is reported (Bundtzen and others, 1982).

CONCLUSIONS AND RECOMMENDATIONS

Among the prospects and mineral occurrences examined during this investigation, the Chip Loy prospect has the best potential for containing significant strategic and critical mineral reserves. Based on the potential size of the Chip Loy prospect, as determined by Smith and Albanese (1985), and the range of cobalt grades that might be encountered, as estimated in this report, from 100 thousand to 4 million lb of cobalt may be present there. Uncertainties exist, however, regarding the recoverability and extent of these resources.

Cobalt at the prospect is intimately associated with iron and nickel in minerals of the linnaeite group and procedures that will selectively concentrate these minerals, so that cobalt can be recovered, must be determined. It is recommended that samples weighing upwards of several hundred pounds be collected for beneficiation tests by Salt Lake Research Center from relatively unweathered rock representing the different types of mineralization present, including massive and disseminated sulfide-bearing rock. Collection of these samples will require either overland access by snowmachine when the ground is frozen.
and snow-covered or considerably more helicopter time than was allocated to the present investigation.

Much more detailed and quantifiable data is needed to determine the true extent of sulfide minerals and metal content at the prospect. Because of the friable character of the rock and the steepness of the outcrop at the prospect, comprehensive and detailed surface mapping and sampling will be very tedious, considerably dangerous, requiring the careful experienced use of technical rock climbing gear and techniques, and because of the weathered sulfide minerals near the surface will even then be of limited benefit. Definative assessment of the prospect's potential can only be achieved by diamond drilling and perhaps some underground exploration. Diamond drilling from the surface will probably require substantial casing to prevent circulation loss in the badly fractured rock. Drilling equipment other than that currently on hand at AFOC will be required.

Although cobalt was reported by Smith and Albanese (1985) at several of the sulfide mineral occurrences and prospects in the area, only the Chip Loy prospect appears to constitute a significant cobalt resource. It is recommended that any efforts in the area by the Bureau be concentrated on evaluation of the Chip Loy prospect and that this evaluation be funded and conducted at a level equal or greater to that typically done by AFOC in the last several years.
REFERENCES


Bundtzen, T.K., 1985, Personal communication, 3 1:63,360-scale map sheets.


**Geochemical Lab Report**

**REPORT:** V88-13351.0

**PROJECT:** A/K/KM/KK/KM

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*Camp Concentrated rocks*

**C2 AK 24265C-CON**

- Au: 0.4 PPM
- Pt: 74 PPM
- Ag: 520 PPM
- Co: 120 PPM
- Cu: 1200 PPM

**C2 AK 24265D-CON**

- Au: 0.6 PPM
- Pt: 130 PPM
- Ag: 780 PPM
- Co: 200 PPM
- Cu: 1900 PPM

**C7 AK 24192C-CON**

- Au: 0.1 PPM
- Pt: 22 PPM
- Ag: 136 PPM
- Co: 30 PPM
- Cu: >5000 PPM

**C2 AK 24397D-CON**

- Au: 0.7 PPM
- Pt: 47 PPM
- Ag: 220 PPM
- Co: 60 PPM
- Cu: 2200 PPM

**C2 KW 24524B-CON**

- Au: 22.8 PPM
- Pt: 853 PPM
- Ag: >20000 PPM
- Co: >20000 PPM
- Cu: 1050 PPM

*Roberts PGM Plant core*:

- Au: 876 PPM
- Pt: 40 PPM
- Pd: 25 PPM

- Au: 82 PPM
- Pt: 40 PPM
- Pd: 30 PPM

- Au: 327 PPM
- Pt: 20 PPM
- Pd: 15 PPM

- Au: 208 PPM
- Pt: 30 PPM
- Pd: 20 PPM

- Au: 237 PPM
- Pt: 960 PPM
- Pd: 940 PPM

*Roberts PGM 80 g split from 5.8 kg sample*

- Au: >10000 PPM
- Pt: >20000 PPM
- Pd: 200 PPM

- Au: 570 PPM
- Pt: 30 PPM
- Pd: 35 PPM

**Assays received 7/22**

- Howard Roberts file
- A/K/KM/KK/KM field report
- PGM file

---

For your information and to insert in your copy of Kuskiekew field report.
J.S. Bureau of Mines
Field No. KU 24524

Date: 7/25/86
Prospect: Robert Pan
Section: 5-1/4
Town: K.
Meridian: 33S

Sample Date: July
Sample No.: 24524

Sample type: o representative, o high-grade, o bedrock, o rubble, o float
Sample weight: 20 lbs

Chip, random, o pan concentrate, o chip, continuous, o sluice box, o grab, o stream sediment, o channel, o stream pebble, o soil, depth, o water

NOTES (see list)

Sample analyzed by:

Lab instructions:

Lab no. A6-003

Major Oxides:

Material and Be, looked around, but no similar rocks, outside the immediate area.

Teaser,

Sulfides are Cu and Zn,
disseminated. See 245-25-

50g flat cone, split received from
Bill O'Connor in ore.

PS made, remainder sent to
Dinsdale-Chipp for INAA PKA,
En, Ni, Cu, Pt.

Also 2, 200gms head splits
1 pulverized - split 133 x 1
1 not pulv. rec'd. 28/6
May 25, 1988

Memorandum

To:        Jeff Foley, Geologist, Alaska Field Operations Center, Fairbanks
From:      Group Supervisor, Minerals Engineering
Subject:   Samples from Robert's PGM occurrence

The analyses on the subject samples requested in your memo of December 1987, have been completed. The results are described in the attached petrographic report that was prepared by Bill O'Connor. Splits of the heads and concentrates are being sent to you for future reference.

A. R. Rule

Enclosure
The 5.9 kg sample from the Robert's PGM occurrence was crushed, weighed, and concentrated by sulfide flotation. Analyses for Au, Pt, Pd, Cu, Co, and Ag were conducted on splits of the head and the concentrate. Polished sections were prepared from the ore sample, and from each of the concentration products (rougher concentrate, scavenger concentrate, and flotation tailings). These were initially examined by reflected light microscopy to identify the general sulfide mineralogy. The sections were then examined by SEM for identification of particularly rare and/or fine grained constituents. Characterization determinations from the ore and the concentration products follow.

Ore Samples

Characterization of the ore sample was initiated on the reflected light microscope. Pyrrhotite was identified as the major sulfide constituent, followed by chalcopyrite. Sphalerite and pyrite, while significant phases in the concentrate, were not present in the selected ore sample. Several of the pyrrhotite grains were rimmed by a phase exhibiting a peculiar "skeletal" texture (figure 1). The structure consisted of dark outlines with lighter cores, and was not positively identified in reflected light. Difficulty in discerning the transition between the light and dark zones made the general analytic techniques ineffective. Possibilities ranged from pyrrhotite making up the outline of the skeleton with chalcopyrite in the core, to a single phase exhibiting a zonation phenomenon.

Subsequent examination of the ore sample on the SEM led to positive identification of the phase. Chemistry, determined by x-ray analysis, included Fe, Ni, and Co. The peculiar skeletal framework is due to variations in Ni content within the phase, bravoite (Fe,Ni,CoS₂). Light areas (on SEM photomicrograph) are zones of higher Ni concentration, with zones of lower Ni content appearing darker (figure 2). The presence of the bravoite explains the values of Co reported in the chemical analyses.

The polished section of the ore was also scanned by the SEM for PGMs. A few tiny (10 microns) grains were located. Each grain consistently contained palladium, with varying amounts of bismuth, tellurium, and/or antimony (these will be described in somewhat more detail in the ensuing section). Within the ore sample, these grains were observed to occur as free particles within the matrix and as inclusions in the pyrrhotite.

Concentration Products

Initial characterization of the flotation products determined the primary sulfide phase present in the products is again pyrrhotite, as in the ore sample. Pyrite occurs in minor abundance. Much of pyrrhotite is rimmed
with a blue-gray phase (in reflected light), goethite. Chalcopyrite is the next most abundant phase, often containing inclusions of or middled with sphalerite. However, sphalerite occurrence is minor. Despite the middling of chalcopyrite and sphalerite, overall liberation is very good. Grade is very low, even in the flotation concentrate, as illustrated in the chemical analyses.

The tailings sample contains several extremely fine (10 microns), highly reflectant (70 pct), white grains, with very low Vicker's microhardness (100, compared with 1500 for pyrite). Galena was ruled out as a possible identification, and subsequent examination on the SEM led to identification of similar grains as a palladium-bismuth-telluride (figure 3). A specific mineral name may be difficult to establish, but palladium-bismuthide or some similar phase is likely.

The limited number of samples studied makes identification of all the elements that were chemically analyzed difficult. The concentration of Ag, at 0.2 oz/ton in the head and 0.36 oz/ton in the concentrate, indicates a fairly significant occurrence. However, identification of any Ag phases was not successful. A more complete study of a greater volume of material might lead to the successful identification of the source of the silver, whether it be present as a separate phase or in solid solution with one of the other sulfide phases. Gold values were rather low, but further study might prove beneficial for Au characterization as well.

Bill O'Connor
Metallurgist
Albany Research Center
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REMARKS: CORRECTED REPORT 3-4-88
ANALYST: SUPERVISOR: VALUES REPORTED AS %
March 6, 1988

Memorandum

To: W. K. O'Connor, Metallurgist, ALRC

From: Research Supervisor, RERC

Subject: Sample Analysis

Enclosed are the analytical results on the samples you submitted February 15, 1988.

Kenneth G. Broadhead
## SAMPLE ANALYSIS REPORT

**Submitted by:** Broadhead  
**Date of Request:** 2/22/88  
**Date Received:** 2/22/88

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**Remarks:**

2536: Ro. Sulf. Flot. Con  
2537: Scav. Sulf. Flot. Con  
2538: Flotation Tails  
2539: Head

**Reported as:**

A. g/l  
B. mg/ml  
C. %  
D. ppm  
E. oz/ton  

element unless otherwise noted
oxidel

**Analyst:** F. Godsey  
**Date Completed:** 2/25/88

**Date:** Month Date Year
### SAMPLE ANALYSIS REPORT

**Samples submitted by:** Brockon

**Date:** 2/23/88

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**Remarks:** Sample size = 0.1 A.T.

Reported as:
- A. g/l
- B. µg/ml
- C. %
- D. ppm
- E. oz/ton
- F. wt/%
- G. element
- H. oxide

(Unless otherwise noted)

**Analyst:** W. Bang

**Date:** 2/29/88