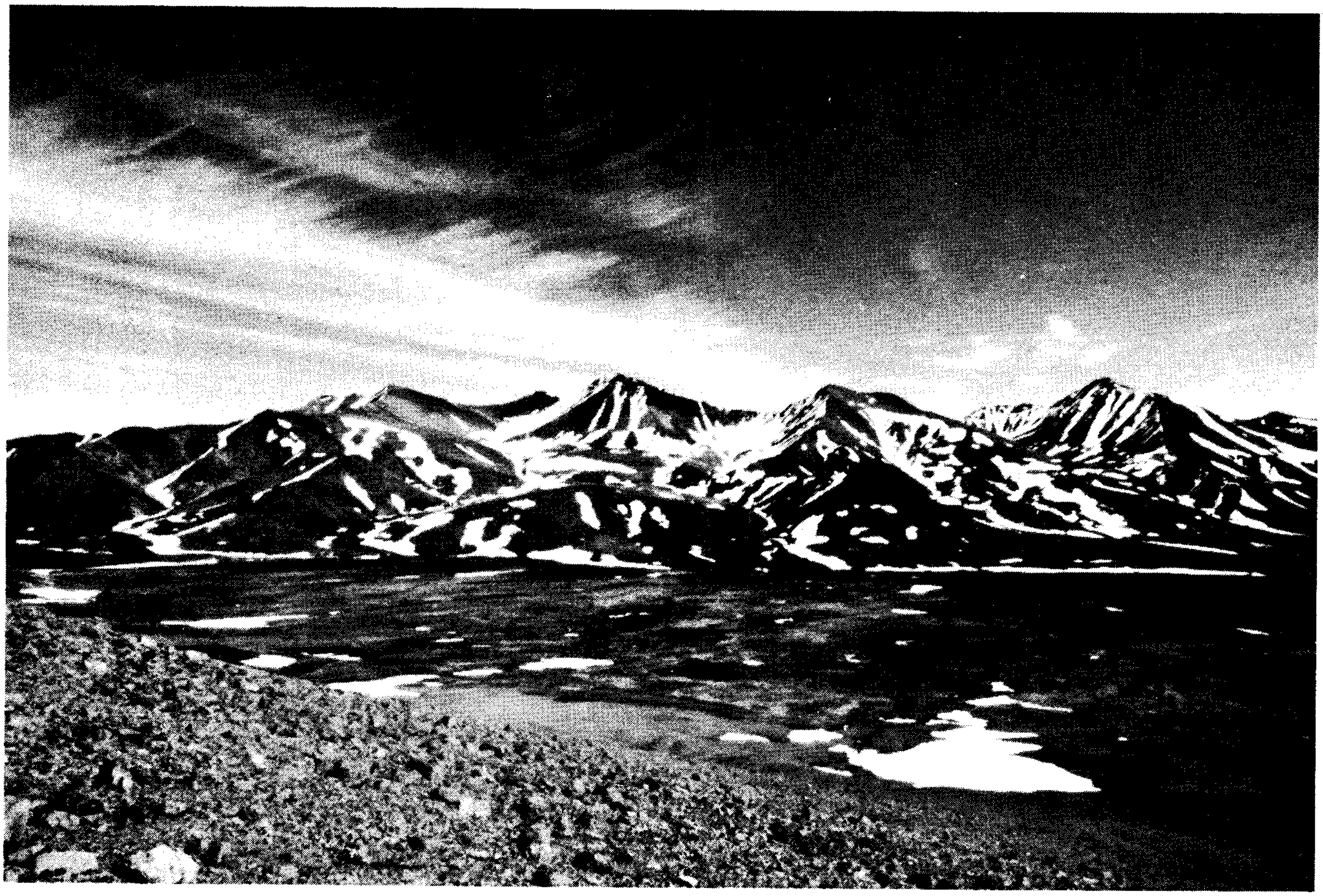
RECONNAISSANCE INVESTIGATIONS OF CHROMITE DEPOSITS AND PLATINUM-GROUP METALS IN THE WESTERN BROOKS RANGE, NORTHWESTERN ALASKA

By Jeffrey Y. Foley, David C. Dahlin, Cheryl L. Mardock, and William K. O'Connor



UNITED STATES DEPARTMENT OF THE INTERIOR

Manuel Lujan, Jr., Secretary

BUREAU OF MINES

T S Ary, Director

Open File Report

OFR 80-92

PREFACE

To ensure that mineral supplies are adequate to meet the Nation's needs, the Bureau of Mines is currently reviewing and investigating numerous reported occurrences of strategic and critical minerals in Alaska. Strategic and critical minerals include those that are essential to industry and defense, that are obtained from foreign sources, and for which no satisfactory domestic substitutes are known. This report is one of several on chromite deposits and platinum-group metals in Alaska by the Bureau's Alaska Field Operations Center and the Bureau's Albany (OR) Research Center.

CONTENTS

ILLUSTRATIONS

TABLES

UNIT OF MEASURE ABBREVIATIONS

in.	inch	pct	percent
ft	foot	ppb	part per billion
lb	pound	ppm	part per million
mi^2	square mile	st	short ton
oz	troy ounce	wt pct	weight percent
oz/st	troy ounce per short ton		

RECONNAISSANCE INVESTIGATIONS OF CHROMITE DEPOSITS AND PLATINUM-GROUP METALS IN THE WESTERN BROOKS RANGE, NORTHWESTERN ALASKA

By Jeffrey Y. Foley,[1] David C. Dahlin,[2] Cheryl L. Mardock[3], and William K. O'Connor[2]

ABSTRACT

Chromite deposits and platinum-group metal (PGM) occurrences in the western Brooks Range, northwestern Alaska, were briefly investigated several times during the period 1981 to 1991 as part of the Bureau of Mines strategic and critical minerals studies. Deposits that contain massive shipping-grade chromite (>40 pct chromite) are relatively small and insignificant. More numerous and larger low-grade stringer zone deposits that contain between 3 and 15 pct chromite and measure up to 175 by 2,000 ft were identified and described. Based on surface measurements, minimum identified chromite resources are between 710 thousand and 2.3 million short tons of chromic oxide (Cr_2O_3). Metallurgical tests indicate that high-chromium chromite concentrates suitable for metallurgical uses can be recovered from these low-grade deposits by gravity concentration procedures.

Evidence collected during these investigations indicates that lode PGM occurrences exist in the region. At Misheguk Mountain, bedrock samples of high-iron chromitite were found to contain as much as 0.27 oz/st PGM (4,700 ppb Pd, 4,200 ppb Pt, 280 ppb Rh, 120 ppb Ir, and 75 ppb Ru). Sperrylite ($PtAs_2$) was identified in specimens from this site. Elevated PGM and gold concentrations were also detected in tabled chromite concentrates, chromitites, and sulfide mineral-bearing gabbroic rocks at other sites throughout the western Brooks Range.

Placer chromite deposits with byproduct gold and PGM may exist in valleys that drain the chromite-bearing ultramafic rocks and related mafic igneous rocks. Placer samples contain high chromium concentrations and samples collected at several sites were found to contain elevated concentrations of PGM and gold.

[1]Geologist, Alaska Field Operations Center, Bureau of Mines, Anchorage, AK.
[2]Metallurgist, Albany Research Center, Bureau of Mines, Albany, OR.
[3]Geologist, Albany Research Center.

INTRODUCTION

The purpose of this investigation is to assess the chromite resources in areas of northwestern Alaska that are known or suspected to contain chromite and to identify and characterize areas that contain platinum-group metals (PGM) and other valuable mineral resources.

The Bureau of Mines Alaska Field Operations Center (AFOC) mapped and sampled chromite occurrences in ultramafic rocks in four separate areas in the western Brooks Range during the periods 1981 to 1983 and 1988 to 1991. These areas (fig. 1) include Iyikrok Mountain, Avan Hills, Misheguk Mountain, and Siniktanneyak Mountain. Asik Mountain, also reported to contain chromite (28)[4], was not investigated by the Bureau. Field work was conducted from mobile, two- and four-person tent camps that were transported by light fixed-wing aircraft and helicopter. Chromite occurrences and deposits were described in the field and are summarized this report.

This report presents the results of geochemical analysis for samples collected during the 1981-1983 investigations and highlights the results of data for select samples that were collected during the 1988, 1989, and 1991 investigations. Complete results of the later investigations will be presented in subsequent reports[5].

The Bureau's Albany Research Center (ALRC), Albany, OR, conducted mineralogical and beneficiation studies on 10 bulk samples from 8 of the larger chromite occurrences. These samples included three from Iyikrok Mountain, five from the Avan Hills, and two from Misheguk Mountain. Five additional samples were collected in 1989 from an additional chromite deposit in the Avan Hills; these samples are currently being characterized and beneficiated at the Bureau's Salt Lake City, UT Research Center (SLRC). Preliminary data for the 1989 samples are summarized in this report.

CHROMITE USES AND DOMESTIC DEPENDENCE

Chromite $[(Fe,Mg)(Cr,Al)_2O_4]$ is the ore mineral of chromium, a metallic element that has a wide range of uses in the metallurgical, chemical, and refractory industries. Chromium is essential in the manufacture of stainless and corrosion-resistant steels, is used extensively in the production of ferrous and nonferrous alloys, and has a variety of other industrial uses for which there are no satisfactory substitutes (24,25). The United States imports all of its chromite ore and concentrates, and most of its ferrochromium alloys; consequently, chromium is one of the Nation's most important strategic and critical materials. Summaries of chromium and chromite uses, supplies, recycling statistics, and chromium technology are contained in the Bureau of Mines Minerals Yearbook chapter on chromium (25) and Mineral Commodity Summaries (30).

PREVIOUS WORK

Published results of geologic studies in the western Brooks Range include descriptions of the ultramafic and associated rocks, geologic maps, geochronologic data, and geophysical data. Patton and others (26) first described the ophiolitic nature of the ultramafic and associated rocks in the western Brooks Range. Roeder and Mull (27) and Mull (21) discussed the tectonic evolution and structure of the Brooks Range and

---

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

[5] Analytical data for samples collected in 1988, 1989, and 1989 are available upon request from Jeffrey Y. Foley, Bureau of Mines Alaska Field Operations Center, Anchorage, Alaska.

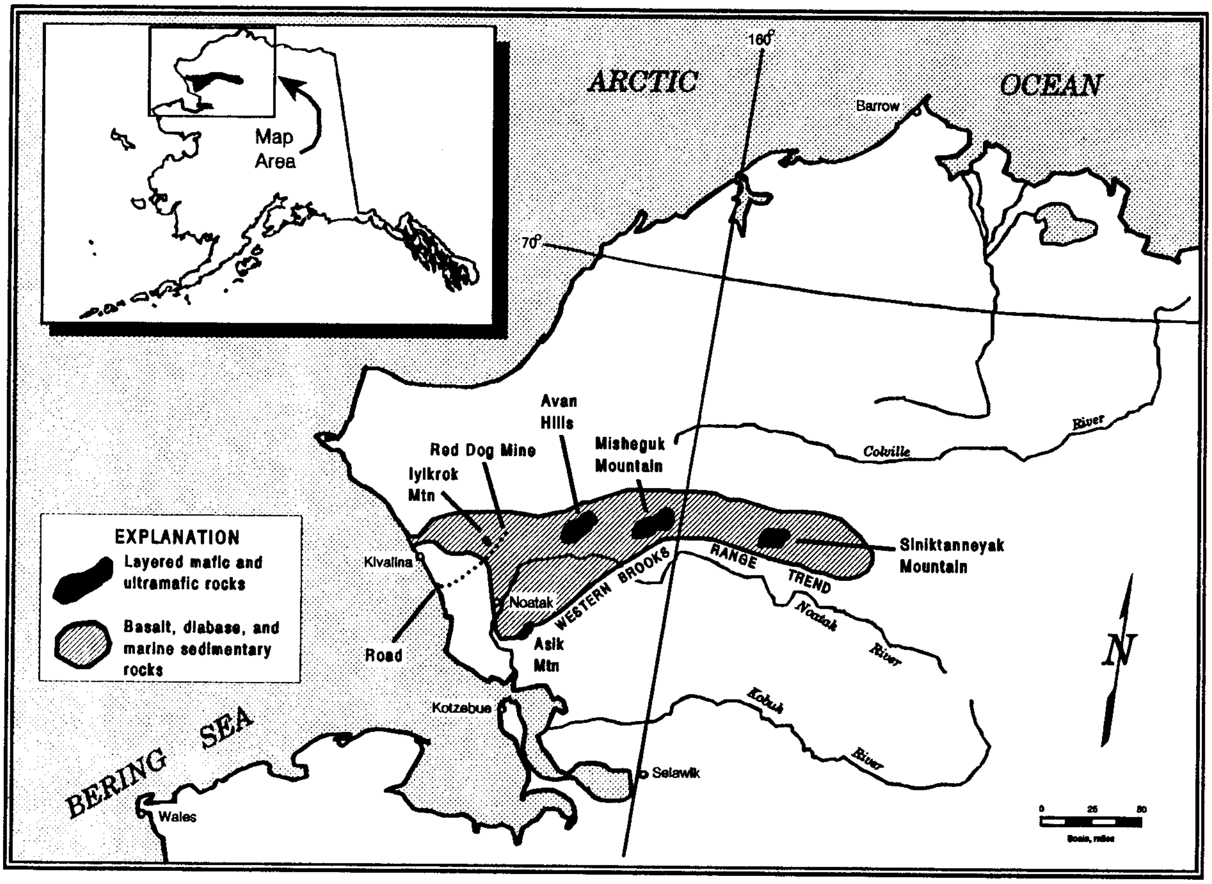


Figure 1. - Map of northwestern Alaska showing features mentioned in text.

related ophiolites in northern and western Alaska. Mayfield and others (20) described the stratigraphy and structure and presented a palinspastic synthesis and a 1:1,000,000-scale geologic map of the western Brooks Range. Gravity data for the region, which clearly depict the areal extent of the ultramafic rocks, are presented on two maps by Barnes (3,4) and interpretations of gravity and magnetic data are contained in a report by Barnes and Tailleur (5). Several of the ultramafic complexes discussed in this report were studied in detail by other investigators. Zimmerman and Soustek (32) described the Avan Hills ultramafic complex. Volcanic, sedimentary, and mafic plutonic rocks in the Avan Hills were mapped and described by Zimmerman and others (31), Frank and Zimmerman (12), and by Curtis and others (6,7). Geologic maps of Misheguk Mountain are contained in reports by Ellersieck and others (9), Curtis and others (6), and Mayfield and others (20). A geologic map of the Siniktanneyak Mountain ophiolite was compiled by Nelson and Nelson (22). Geochronologic, structural, petrologic, and chemical data and an interpretation of the emplacement history of the Misheguk Mountain ophiolite mass are contained in abstracts by Harris (13,14). Harris also completed a Ph.D. dissertation on the Misheguk Mountain ophiolite, which he compares to other ophiolites in Alaska and southeast Asia (15).

References to chromite occurrences in ultramafic rocks in the western Brooks Range are contained in earlier geologic reports by Saunders (28), Degenhart and others (8), U.S. Bureau of Mines (29), Jansons and Baggs (16), Zimmerman and Soustek (32), Nelson and Nelson (22), and Foley and others (10,11). Saunders (28) described two chromite occurrences at Asik Mountain, and Jansons and Baggs (16) described one occurrence at Siniktanneyak Mountain.

None of the lode chromite deposits in the western Brooks Range have been mined or examined in detail by industry. Verbal reports indicate that a mining company evaluated placer deposits in the Avan River Valley for PGM in the late 1960's. Inquiries by the Bureau, however, failed to substantiate these reports.

More recently, Mowatt and Jansons (17) and Mowatt (18,19) reported high PGM values in sulfide-bearing gabbroic rocks from the Asik Mountain, Avan Hills, Misheguk Mountain, and Siniktanneyak Mountain ophiolite masses.

GEOGRAPHY AND ACCESS

Areas described in this report are in the De Long Mountains, which are the westernmost extension of the Brooks Range, in northwestern Alaska. Kotzebue is the regional trade and transportation center. The Chukchi Sea, which lies to the west, is generally ice-free and suitable for barge transport by late June or early July. Navigable open-water conditions usually persist through November.

There are no roads within the investigated areas and most of the rivers in the region are too shallow to navigate; only the lower Noatak River is passable by freighting barges. An unpaved airstrip, suitable for Boeing 737-type and smaller aircraft, is maintained at Northwest Alaska Native Association (NANA) Corporation's Red Dog zinc-lead-silver Mine (fig. 1). Smaller, primitive airstrips exist at Iyikrok Mountain and on gravel bars along the Avan and Kelly Rivers near the Avan Hills, and along Okotak and Trail Creeks, near Misheguk Mountain. Asik Mountain and Siniktanneyak Mountain are situated near lakes that are accessible by floatplanes. Because of the vastness of the region and the steep terrain, geologic and mineral investigations are most efficiently conducted with helicopter support.

In the future, some of the chromite deposits may become more accessible. Iyikrok Mountain is about 8 miles from the road between the Red Dog Mine and the port site near Kivalina (fig. 1). The Avan Hills lie about 20 miles east of the Red Dog Mine; Misheguk Mountain and Siniktanneyak Mountain are farther to the east.

LAND STATUS

The Avan Hills, Misheguk Mountain, and Siniktanneyak Mountain are located within the Noatak National Preserve in areas closed to mineral entry. These areas are administered by the National Park Service, U.S. Department of the Interior. Portions of Iyikrok Mountain in T29N, R21 and 22W, Kateel River Meridian, have been classified as lands suitable for State selection. These areas are currently administered by the Bureau of Land Management, U.S. Department of the Interior. The T30N, R21W and 22W area has been selected by the State of Alaska and the selection of T30N, R21W has been tentatively approved. Native selections have also been filed for small portions of T30N, R21W. Two regional historical selections by native corporations include T30N, R21W.

Portions of Siniktanneyak Mountain in T12S, R1-3E, Umiat Meridian, have been conveyed to the Arctic Slope Regional Corporation. Lands in T34N, R1-3E, Kateel River Meridian, are within the Noatak National Preserve, administered by the National Park Service, and are closed to mineral entry.

GEOLOGIC SETTING

The De Long Mountains and adjacent areas in the western Brooks Range are underlain by folded and faulted sedimentary rocks of Devonian to Cretaceous age. This sedimentary sequence is, in places, up to 26,000 ft thick and consists mostly of carbonates and fine-grained clastic rocks (21). The sedimentary rocks occur as stacked thrust sheets that have been locally intruded by mafic and felsic igneous rocks. In places, the folded and faulted sedimentary rocks are structurally overlain by a sequence of rocks comprising an upper tectonic unit of crudely layered mafic and ultramafic rocks, and a lower tectonic unit of basalt, diabase, and marine sedimentary rocks (fig. 1). On the basis of fossil evidence and radiometric age data, Paleozoic to Mesozoic ages are indicated for the lower and upper tectonic units (26). These two tectonic units, separated from the underlying sedimentary rocks by thrust faults, are erosional remnants (klippen) of extensive sheets of ocean floor material (20, 26,27). The klippen were emplaced in their present positions during the Jurassic period by thrust faulting (14,15) and the stacked sequence preserved in the western Brooks Range is the reverse of that normally found in better-preserved ophiolites.

Ophiolite masses that contain upper, lower, or both tectonic units are distributed along a 200-mile, east-trending belt in the western Brooks Range that extends from the Chukchi Sea to Howard Pass. The four largest ultramafic-layered gabbro complexes occur at Asik Mountain, Avan Hills, Misheguk Mountain, and Siniktanneyak Mountain. Ultramafic rocks at Iyikrok Mountain are but a small part of a much larger klippe that comprises mostly volcanic rocks of the lower tectonic unit (fig. 1).

PROCEDURES AND TERMINOLOGY

Rock samples collected during the period from 1981-1983 were analyzed for chromium by atomic absorption and inductively coupled plasma procedures. Alluvium samples were panned to produce heavy mineral concentrates that were analyzed for chromium, gold, and PGM. Splits of rock and panned concentrate samples were preconcentrated by fire-assay procedures prior to precious metal analysis by inductively coupled plasma in 1981 and 1982 and fire-assay atomic absorption procedures in 1983. Pan samples and rock samples with more than 2 pct Cr were analyzed for chromium by atomic absorption using peroxide fused splits.

In this report, chromite deposits are differentiated from chromite mineral occurrences. A chromite occurrence is an unmeasured concentration of the mineral and has no resource or economic connotation.

A chromite deposit is a concentration of chromite that has a definable size and is large enough to warrant investigation as a mineral resource. Resource estimates are calculated and presented as short tons of contained Cr_2O_3.

Mineral resource estimates were made for each deposit by estimating the chromium and chromite content on the basis of field observations and analytical data and measuring the extent of the deposit at the surface. Deposits that were covered by snow or regolith at one end or on one side were assumed to be 1.25 times as long or wide as measurements indicate. Deposits covered at two ends or on two sides were assumed to be 1.5 times as long or wide as measurements indicate. The down-dip extent of each deposit was assumed to be 0.25 to 0.5 times the estimated strike length.

By convention, chromite concentrates are classified on the basis of their chromium-to-iron (Cr-Fe) ratios and their chromium, iron, aluminum, and magnesium oxide contents. High-chromium (metallurgical-grade) concentrates contain a minimum of 46 pct Cr_2O_3 and have Cr-Fe ratios of 2.0:1 or greater. High-iron (chemical-grade) concentrates contain from 40 to 46 pct Cr_2O_3 with Cr-Fe ratios from 1.5:1 to 2.0:1. High-alumina (refractory-grade) concentrates contain greater than 20 pct aluminum oxide (Al_2O_3), and the total Al_2O_3 plus Cr_2O_3 content exceeds 60 pct (24).

Ten bulk samples were collected in 1983 from eight deposits for metallurgical tests including mineralogical characterization and beneficiation studies at ALRC. The bulk sample weights ranged from 10 to 62 lb. Representative specimens were selected from each bulk sample for mineralogical characterization. Detailed mineralogical and liberation studies were done on sized fractions of head sample splits and on beneficiation products. Binocular and petrographic microscopy, magnetic separation techniques, sizing procedures and, as needed, scanning-electron microscopy and electron-microprobe examinations were used to determine mineral compositions. Scanning-electron microscopy was also used to search for PGM minerals in splits of each sample. Except for samples collected during later investigations, no PGM minerals were found.

High-purity chromite concentrates were produced from gravity table concentrates by controlled magnetic separation on a laboratory-model isodynamic magnetic separator. Fractions representing the purest chromite mineral concentrate from each sample were selected with the aid of a microscope and the fractions were then chemically analyzed.

All specimens examined at ALRC and SLRC are composed of ultramafic rock types, predominantly peridotites that contain variable amounts of olivine and pyroxene. Specific rock types present in the samples include dunite (>90 pct olivine), pyroxene peridotite (a mixture of olivine and pyroxene), pyroxenite (>60 pct pyroxene), serpentinite (a mixture of serpentine mineral varieties), and chromitite (nearly all chromite). Because field investigations were primarily concerned with chromite resources, traverses were concentrated in areas underlain by dunite and little time was spent examining and sampling gabbroic rocks.

Minerals identified in petrographic specimens selected from the 10 bulk samples include abundant chromite or chromium-bearing spinels, ferromagnesian silicate minerals (including olivine, pyroxene, and amphibole), serpentine, and minor magnetite, kammererite (a chromian chlorite), and sulfide minerals, including an unidentified nickel-iron sulfide mineral. Chromites in most of the samples are magnesian-aluminian varieties that may also be classified as high-chromium chromite with Cr-Fe ratios that range from 2.5 to 3.4.

Six morphological types were recognized in chromite-bearing dunite samples from the western Brooks Range. These structures include disseminated, banded, nodular, coalescent, massive, and irregular segregations (schlieren). Locally, chromite occurring in these morphological types and combinations thereof are contained in zones referred to in this report as banded zones and stringer zones. These zones are interpreted as the surface expression of 3-dimensional masses for which dimensions are estimated as described earlier in this section. Banded zones comprise chromite layers that are continuous for several tens of feet or more. Stringer zones comprise discontinuous chromite layers (lenses), disseminated chromite, massive chromite, and chromite schlieren.

Disseminated chromite (fig. 2) comprises individual chromite grains randomly scattered throughout serpentinized dunite. The chromite grains may be closely disseminated (nearly touching) to sparsely disseminated. In some cases, the chromite grains have been stretched.

Banded chromite (fig. 3) comprises lens-shaped layers of disseminated, coalescent, or massive chromite in serpentinized dunite.

Nodular chromite (fig. 4) is less common than the disseminated and banded varieties. It consists of spherical or ellipsoidal nodules or clots of chromite in serpentinized dunite. The nodules are usually distributed evenly throughout the rock. An inverse form of this nodular fabric consists of olivine clots or nodules within a massive chromite matrix.

Massive chromite (chromitite) (fig. 5) is primarily chromite with little or no intergranular gangue minerals.

Coalescent chromite (fig. 6) is intermediate to the disseminated and massive forms. The chromite crystals are in contact at several points creating a chromite network within the matrix, which in most cases is finer-grained dunite.

Irregular discontinuous chromite segregations consist of disseminated, coalescent, or massive chromite and are universally referred to as schlieren (fig. 7).

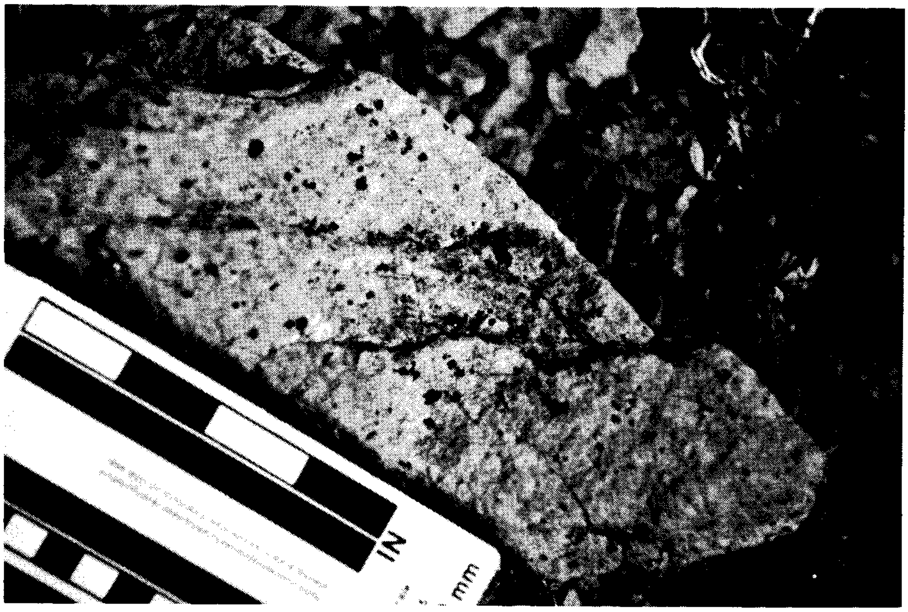


Figure 2. - Photograph of coarse disseminated chromite in dunite in the Avan Hills.

Figure 3. - Photograph of banded chromite in dunite at Siniktanneyak Mountain.

Figure 4. - Photograph of nodular chromite in dunite in the Avan Hills.

Figure 5. - Photograph of massive chromite in dunite in the Avan Hills.

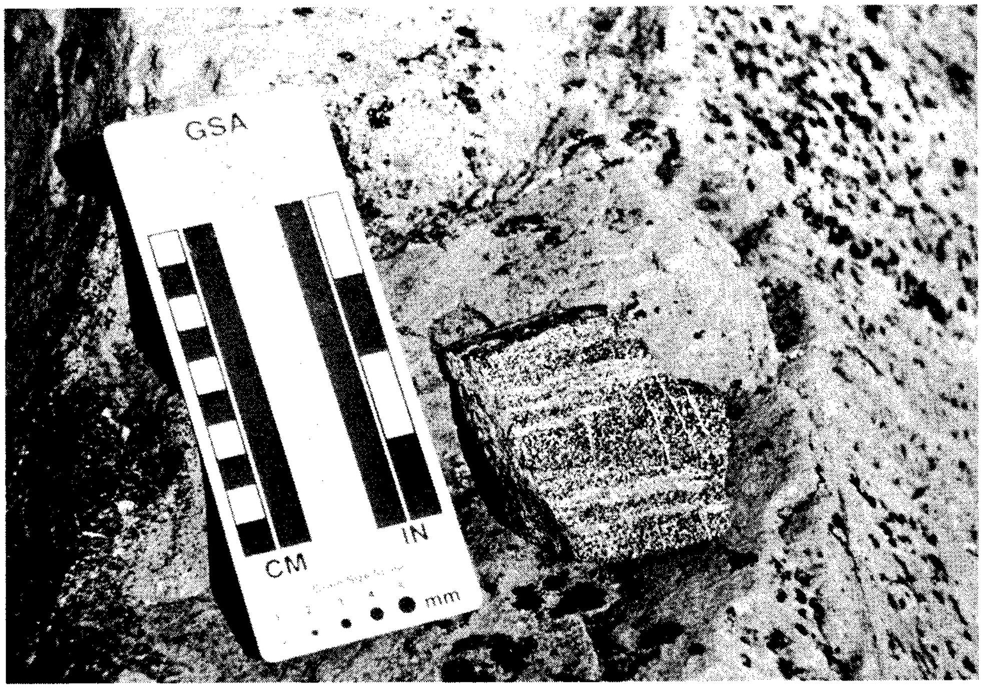
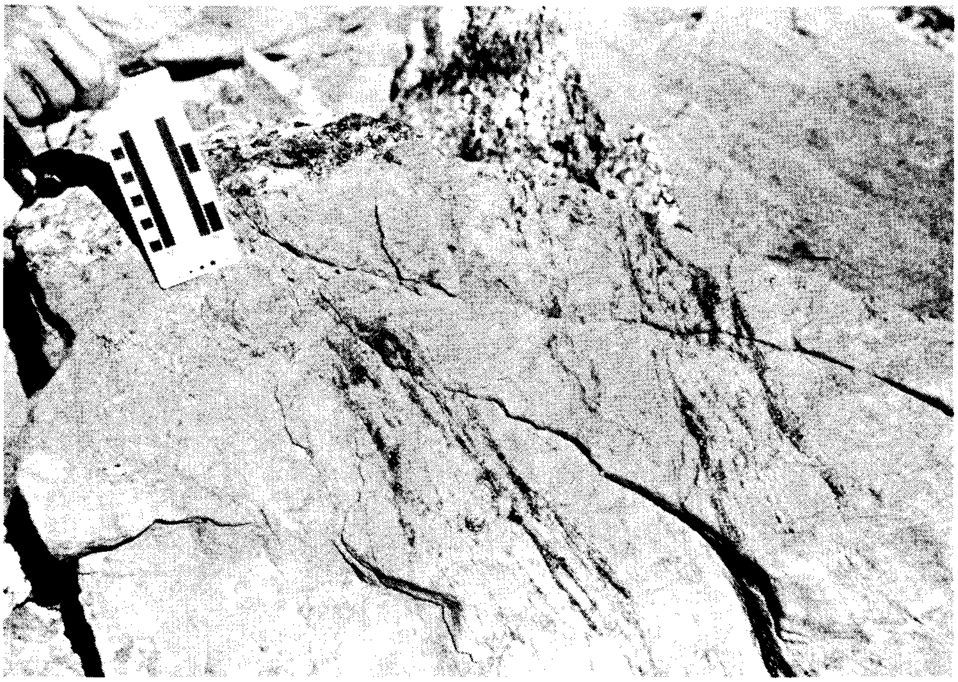
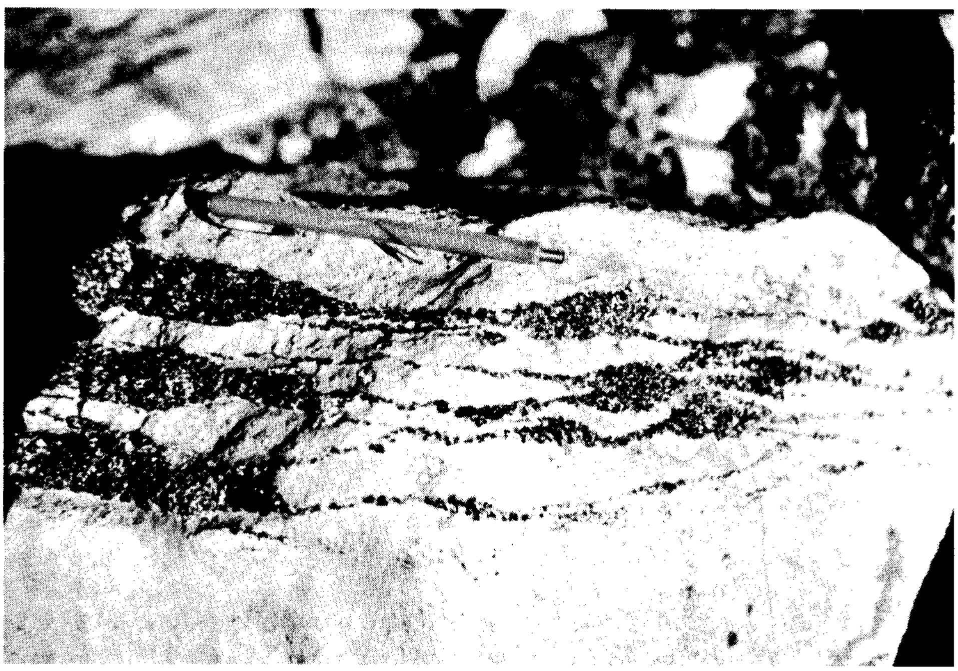


Figure 6. - Photograph of banded coalescent chromite in dunite in the Avan Hills.



7A



7B

Figure 7. - Photographs of chromite schlieren in dunite. Wispy, subparallel chromite schlieren at the Avan Hills (7A) and pinching and swelling chromite schlieren at Siniktanneyak Mountain (7B).

IYIKROK MOUNTAIN

CHROMITE DEPOSITS

Total estimated resources for two low-grade chromite deposits at Iyikrok Mountain are between 144,000 and 383,000 st Cr_2O_3. The deposits contain from 3 to 4 pct chromite. Evidence, including extensive chromite in talus and rubble outside the measured areas, exists for additional chromite resources in buried extensions at both of these deposits. Smaller and unmeasured lode occurrences are present and the existence of placer chromite deposits is indicated.

Iyikrok Mountain (figs. 1 and 8) lies north of the Wulik River, in the southern Arctic Foothills. A 12-mi^2 mass of reddish-orange-weathering dunite and pyroxene peridotite rises from the Wulik River lowland, at an elevation of about 250-300 ft above sea level, to a 2,195-ft summit. Outcrop is scarce with frost-riven rubble and tundra vegetation covering over 90 pct of the area.

One day was spent mapping and collecting samples at Iyikrok Mountain by the Bureau in 1983 (fig. 8). Appendix A provides an index for field sample numbers and the corresponding sample numbers used in this report. Dimensions, grade, tonnage estimates, and descriptions of chromite deposits are listed in table B-1 in appendix B. Analytical results for rock samples and sample descriptions are listed in table 1.

Dunite, locally containing chromite, and pyroxene peridotite are the only rock types observed above approximately the 300-ft elevation. Below that elevation, tundra vegetation is extensive and no bedrock is exposed. Abundant gabbro, minor basalt, limestone, chert, and obsidian float are intermixed with ultramafic rock fragments in three small creeks draining the north side of the mountain.

Chromite occurrences at Iyikrok Mountain range widely in size, grade, and form. Bands of coalescent to massive chromite, irregular massive chromite segregations, chromite schlieren, and closely-spaced bands of disseminated chromite are exposed in dunite at higher elevations. Accessory disseminated chromite is otherwise ubiquitous in the dunite. Chromite is concentrated within crudely defined layers in two areas comprising low-grade deposits that measure tens to hundreds of feet in width and length. More chromite deposits and occurrences probably exist beneath the extensive vegetation and colluvial cover.

At deposit 1, between 4,600 and 12,100 st Cr_2O_3 are estimated in an 80-ft-wide, 350-ft-long, northwest-trending zone that contains disseminated, coalescent, and massive chromite segregations (fig. 8). Within this area is a 20- by 100-ft area that contains from 5 to 6 pct chromite (fig. 9). The greatest chromite concentrations, within the smaller higher-grade area, are in bands up to 8 in. thick that are traceable for tens of feet in frost-riven rubble and fractured bedrock. Throughout the larger area, narrower, closely-spaced bands of disseminated and coalescent chromite that strike east to northeast, and dip to the north and northwest at 34° to 50°, are more common than the massive bands. In general, the chromite bands average 1 to 2 in. thick. This area pinches out, or is covered at the east end, and disappears beneath tundra at its west end. For 400 to 500 ft to the northwest and in several small areas between 1,500 and 2,500 ft farther to the west, similar concentrations of chromite were observed in patches of frost-riven rubble. This indicates that the chromite concentrations may continue beneath the tundra and may be much larger than shown on the map.

TABLE 1. - Analytical results and descriptions of rock samples from Iyikrok Mountain

Sample	Al (pct)	Au (oz/st)	Co (ppm)	Cr (pct)	Cu (ppm)	Fe (pct)	Mg (pct)	Ni (pct)	Pd (oz/st)	Pt (oz/st)	Description
I2R	3.0	<0.002	170	29.8	<20	9.8	11.7	0.19	<0.002	<0.004	Hand-sorted, coarse-grained, coalescent and massive chromite in red-weathering peridotite.
I3R	5.5	<.002	230	27.8	130	10.0	12.9	.17	<.002	<.004	Hand-sorted, massive chromite in frost-riven rubble.
I4R	.9	<.002	60	8.0	<20	5.7	25.1	.30	<.002	<.004	Grab sample of dunite with pods of massive chromite up to 8 in. thick.
I5R	.7	<.002	63	6.0	<20	6.0	24.6	.30	<.002	<.004	Grab sample of dunite with coalescent chromite in pods about 1.5 ft in maximum dimension.
I6R	3.8	<.002	260	32.6	<20	12.6	9.6	.10	<.002	<.004	Hand-sorted, coalescent and massive chromite in dunite.
I8R	<.1	.002	<9	.1	<20	1.5	2.9	.39	<.002	<.004	Silica replacement of peridotite with open boxworks.

NC Not calculated.

Au, Pd, and Pt were preconcentrated by fire-assay and analyzed by atomic absorption by Bondar-Clegg, Inc., Lakewood, CO. Remaining elements analyzed by Bureau's Reno Research Center, Reno, NV, using inductively coupled plasma techniques.

Figure 9. - Photograph of banded chromite in dunite rubble at deposit 1, Iyikrok Mountain.

At deposit 2 and in the area surrounding sample location I6R(M), between 139,000 and 371,000 st Cr_2O_3 are estimated in a 300- by 1,000-ft area with 3 to 4 pct chromite. This area contains east-striking bands of disseminated, coalescent, and massive chromite as much as 4 in. thick. Banded chromite also occurs in talus, at the head of a southeast-flowing creek, for an additional 2,000 ft to the southeast. It is not known if the zone continues that far to the southeast, or if the chromite-bearing rock observed in the talus was derived solely from the zone exposed further upslope.

METALLURGICAL SAMPLE DESCRIPTIONS

Results of chemical analyses on head samples and estimated mineral compositions of bulk metallurgical samples from Iyikrok Mountain are listed in table 2. Analytical data for tabled chromite concentrates (appendix C) demonstrate that high-chromium chromite is present at Iyikrok Mountain.

Sample I2RM (59.4 lb) consists of 0.25- to 1.25-in.-thick, planar bands of coalescent chromite grains in an olivine matrix that alternate with 0.05- to 0.13-in.-thick olivine layers that contain sparsely disseminated chromite. Brownish-black chromite stands out in relief on weathered surfaces. The unaltered olivine is pale green in color and has a sugary texture. Polished section examination shows that the rock is extensively sheared and fractured on a microscopic scale. No secondary minerals were observed in the fractures. Laboratory tests and microscopic examination indicate that chromite grains in sample I2RM are liberated by grinding to 65 mesh.

TABLE 2. - Analytical results and mineral composition of bulk metallurgical samples from Iyikrok Mountain

	I2RM	I5RM	I6RM
Analytical results:			
Cr_2O_3 (pct)	43.3	45.7	42.5
Fe (pct)	9.9	10.5	11.7
Al_2O_3 (pct)	5.2	5.4	7.7
MgO (pct)	26.9	24.2	21.5
SiO_2 (pct)	11.9	11.9	8.0
Au (oz/st)	<.002	<.002	<.002
Pd (oz/st)	<.003	<.003	<.003
Pt (oz/st)	<.003	<.003	<.003
Mineral composition (wt pct):			
Chromite	85	70	78
Olivine	14	29	18
Serpentine	1	Tr	1
Magnetics[1]	Tr	Tr	Tr
Chlorite[2]	Tr	Tr	1
Sulfides	Tr	Tr	ND
Fe-Mg silicates	ND	ND	Tr
Weight (lb)	59.4	27.5	28.6

ND Not detected.
Tr Trace.
[1] Minerals removable with hand magnet.
[2] Mineralogical variety kammererite.
Au, Pd, and Pt analyzed by fire-assay, atomic absorption at Bureau of Mines Reno Research Center, Reno, NV. Remaining elements analyzed by atomic absorption at Bureau of Mines Albany Research Center, Albany, OR.

Sample I5RM (27.5 lb) consists of coalescent to nearly massive chromite with minor olivine. Olivine is present in an inverse form of the more common nodular texture. The chromite is slightly weathered on exposed surfaces and stands out in relief against the less resistant, weathered olivine. Olivine nodules are ellipsoidal, 0.05 to 0.13 in. in cross section, and 0.13 to 0.38 in. long, and are oriented such that their long axes are parallel to one another. The chromite crystals are anhedral to subhedral and interstices are filled with olivine, serpentine, and minor kammererite. Where chromite is coalescent, the chromite aggregates form thin layers around olivine nodules. Traces of a nickel-iron sulfide mineral are also present in the sample. Examination of polished sections shows that the rock is highly fractured and sheared. Chromite is liberated by grinding to 28 mesh.

Sample I6RM (28.6 lb) consists primarily of nearly massive chromite with minor olivine, but a few specimens contain planar bands of coalescent chromite in an olivine matrix. Exposed surfaces on olivine-rich specimens have buff-colored weathering rinds that average about 0.2 in. thick and are pitted by differential weathering of resistant chromite and less resistant, partially serpentinized olivine. Alternating bands of chromite-rich and relatively chromite-free olivine average 0.75 in. thick. Small amounts of serpentine, kammererite, and an unidentified ferromagnesian silicate mineral are present in intergranular spaces between the chromite grains. The more massive chromite is generally anhedral and the disseminated chromite grains within the planar bands are subhedral. The rock is highly fractured, and individual chromite grains are elongated. Fractures within the massive chromite and olivine contain no secondary minerals. Chromite is liberated by grinding to 65 mesh.

RESULTS OF PLATINUM-GROUP METAL AND GOLD ANALYSES

Trace gold (0.002 oz/st Au) was detected in rock sample I8R (table 1) and trace gold (0.003 oz/st Au) was detected in the minus 28- plus 65-mesh tabled chromite concentrate from sample I5RM (appendix C). No PGM were detected in rock samples from Iyikrok Mountain.

PLACER INVESTIGATION

All pan samples from the Iyikrok Mountain area contain significant quantities of chromium (20-34 pct, table 3). Such high chromium values in pan concentrate samples indicate that chromite can be recovered by gravity concentration procedures from alluvium at Iyikrok Mountain. No anomalous PGM or gold concentrations were detected in pan concentrate samples from streams draining Iyikrok Mountain.

TABLE 3. - Analytical results for pan concentrate samples from Iyikrok Mountain

Sample	Au (oz/st)	Cr (pct)	Pd (oz/st)	Pt (oz/st)
I1P	<0.002	20.1	<0.002	<0.002
I7P	<.002	22.3	<.002	<.002
I9P	<.003	33.5	<.002	<.002
I10P	<.002	31.2	<.002	<.002

Analyses by Bondar-Clegg, Inc., Lakewood, CO. Cr analyzed by atomic absorption after peroxide fusion. Au, Pd, and Pt preconcentrated by fire-assay and analyzed by atomic absorption.

AVAN HILLS

CHROMITE DEPOSITS

Identified chromite resources in the Avan Hills include from 446,000 to 1,550,000 st Cr_2O_3[6]. Of these estimates, from 10,000 to 58,000 st Cr_2O_3 are contained in numerous irregular massive chromite segregations. The massive segregations make up from 5 to 20 pct of the rock, by volume, over areas generally measuring tens of feet in maximum dimension (fig. 10). Most of the chromite in the Avan Hills is contained in much larger, low-grade (3-10 pct chromite) stringer zones of banded, massive, disseminated, and nodular chromite and chromite schlieren.

Figure 10. - Photograph of massive dunite blocks in dunite rubble in the Avan Hills.

---

[6] These estimates are from 131,000 to 888,000 st greater than previously reported estimates for chromite resources in the Avan Hills (10). The larger estimates include deposits identified and described during the 1989 investigations.

The Avan Hills consist of rugged, glaciated ridges that rise to between 4,000- and 5,000-ft elevations. Maximum relief in the area is about 3,000 ft (fig. 11). Exposed bedrock is much more abundant in the Avan Hills than at Iyikrok Mountain. Talus and frost-riven rubble are extensive and there is little vegetation cover.

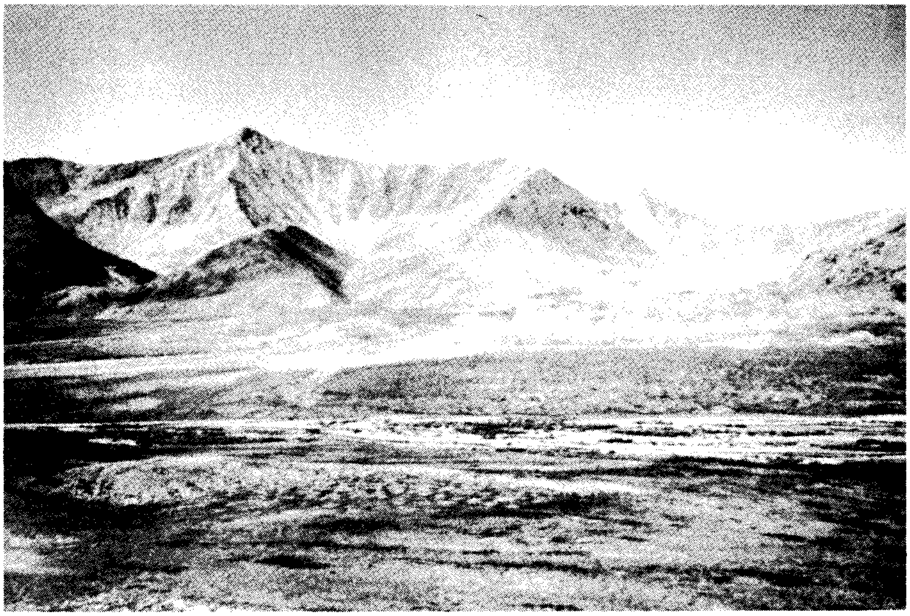


Figure 11. - Photograph of rugged glacier-sculpted ridges in the Avan Hills.

The Avan Hills mafic-ultramafic complex occupies about 130 mi^2 at the north end of an 1,100-mi^2 klippe (fig. 1) that consists mostly of basaltic rocks. This klippe is the largest of the western Brooks Range ophiolite masses (26). The Avan Hills complex is divided into three broad lithologic zones by Zimmerman and Soustek (32):

> In ascending order, they are: (1) a zone of ultramafic tectonites; (2) a transition zone containing both ultramafic and coarse-grained, intermediate and mafic rocks; and (3) a "gabbroic" zone consisting of coarse-grained, intermediate and mafic rocks with mesoscopic and microscopic textures ranging from tectonite to cumulate.

Coarse-grained, crudely layered, gabbroic and intermediate rocks of the transition and "gabbroic" zones occur in the southwestern, northern, and eastern portions of the complex. About three-fourths of the Avan Hills mafic-ultramafic complex is underlain by ultramafic rocks. These include, in decreasing order of abundance, orange-brown-weathering chromite-bearing dunite, reddish-brown-weathering pyroxene peridotite, reddish-orange-weathering olivine clinopyroxenite, green clinopyroxenite, and massive, green-, black-, and white-weathering serpentinite. The mafic and intermediate rocks include gabbro, olivine gabbro, gabbronorite, anorthosite, troctolite, biotite granite, tonalite, and serpentinite (12).

Bureau personnel spent a total of 10 days in the Avan Hills ultramafic complex in 1981, 1982, and 1983. Four additional days were spent working in the area in 1989 by a team comprising geologists from the Bureau, U.S. Geological Survey (USGS), Alaska Division of Geological and Geophysical Surveys (ADGGS), and West Virginia University.

Geology of the investigated area, chromite occurrences and deposits, and sample locations are shown on figure 12. Analytical results and descriptions of rock samples collected in the period from 1981 through 1983 are listed in table 4. Dimensions, grade, tonnage estimates, and deposit descriptions are listed in table B-2 in appendix B.

Chromite occurrences and deposits in the Avan Hills are of three morphological types. The first type consists of irregular segregations of massive chromite in dunite and peridotite (figs. 10 and 13). These segregations are without form or orientation. Typically, anastomosing web-like masses of chromite ranging from several inches to more than a foot in maximum dimension are connected to similar masses by irregular veins an inch or so thick (fig. 13). These massive chromite segregations typically constitute from 5 to 20 pct of fractured bedrock and rubble over an area tens of feet in maximum dimension (fig. 10). Occurrences and deposits of this type were sampled at locations A21R (deposit 15), A24R(M), A31R, A35R, and A36R (deposit 21, fig. 12). Other similar occurrences that were not sampled are also described in figure 12. Northeast and downstream from deposit 15, outside the area shown in figure 12, are many more massive chromite segregations of this type.

Figure 13. - Photograph of irregular massive chromite segregation in the Avan Hills ultramafic complex.

The second type of chromite occurrence and deposit consists of multiple, parallel, banded chromite layers and chromite schlieren. The thickness of individual chromite layers ranges from a fraction of an inch to about 10 in., and chromite concentrations within the layers ranges from several percent disseminated chromite to more than 50 pct coalescent to massive chromite. Overall, stringer zones comprising multiple chromite bands and chromite schlieren with disseminated chromite in dunite typically contain between 3 and 10 pct chromite.

Examples of the second type of chromite occurrence were observed and sampled at locations A27R (deposit 12) and A28R (deposit 17, fig. 12). At sample location A27R (figs. 12 and 14), bands of disseminated and coalescent chromite, ranging from less than 0.5 to 2 in. wide, strike N 20° E and dip

TABLE 4. - Analytical results and descriptions of rock samples from the Avan Hills

Sample	Al (pct)	Au (oz/st)	Cr (pct)	Fe (pct)	Mg (pct)	Pd (oz/st)	Pt (oz/st)	Si (pct)	Description
A3R-A	1.2	<0.002	8.0	6.4	24.9	<0.002	0.004	NA	Representative sample across 10-ft-wide, higher grade portion of stringer zone.
A3R-B	2.4	<.002	17.5	7.4	20.0	<.002	<.004	NA	Hand-sorted chromite-rich material.
A5R	3.1	<.002	15.2	6.7	16.5	<.002	<.004	NA	Representative sample across 23-ft-wide portion of 23- by 55-ft-wide pear-shaped zone of nodular and massive chromite in dunite.
A6R	1.8	<.002	7.0	6.3	19.2	<.002	<.004	NA	Hand-sorted, chromite-rich material from 125- by 200-ft-wide stringer zone.
A7R	.1	<.002	.6	5.7	24.9	<.002	<.004	NA	Grab sample of dunite with accessory chromite.
A8R-A	5.8	.002	24.9	9.7	11.1	<.002	<.004	NA	Hand-sorted chromite-rich dunite.
A8R-B	1.0	<.002	4.9	6.4	22.2	<.002	<.004	NA	Representative sample at A8R-A.
A9R	NA	<.002	NA	NA	NA	<.002	<.004	NA	Hand-sorted chromite-rich dunite from 2- by 20-ft stringer zone.
A10R	5.4	.002	19.3	10.5	14.8	<.002	<.004	NA	Hand-sorted chromite from 20- by 200-ft- stringer zone.
A11R-A	5.8	<.0001	27.6	11.6	10.3	<.001	<.001	NA	Massive chromite grab sample.
A11R-B	5.2	NA	40.9	14.2	9.2	NA	NA	9.0	Chromite grains from A11R-A after crushing.
A12R-A	.5	<.0001	2.2	6.7	4.5	<.001	<.001	NA	Grab sample of dunite with coarse-grained, disseminated chromite.
A12R-B	2.8	NA	22.1	12.0	15.4	NA	NA	23.0	Chromite grains from A12R-A after crushing.
A13R	.4	<.002	1.4	6.3	25.4	<.002	<.004	NA	Composite grab sample from low-grade stringer zone.
A14R	.9	<.0001	2.2	6.9	23.6	<.001	<.001	NA	Grab sample from zone with discontinuous chromite bands.
A15R	NA	<.0002	NA	NA	NA	<.0003	<.0003	NA	Grab sample from 2-in.-thick massive chromite band.
A16R	5.2	<.002	30.1	11.1	13.1	<.002	<.004	NA	Hand-sorted coalescent and massive chromite.
A17R	2.5	<.002	8.5	9.0	24.1	<.002	<.004	NA	Grab sample from 90- by 150-ft stringer zone in serpentinized peridotite with 4 pct chromite. 25- by 90-ft portion contains 12 to 20 pct chromite.

TABLE 4. - Analytical results and descriptions of rock samples from the Avan Hills - continued

Sample	Al (pct)	Au (oz/st)	Cr (pct)	Fe (pct)	Mg (pct)	Pd (oz/st)	Pt (oz/st)	Si (pct)	Description
A18R-A	4.4	<.0001	28.9	9.9	13.9	<.001	<.001	NA	Hand-sorted chromite-rich dunite from 10-ft-thick zone with bands of massive chromite up to 4 in. thick.
A18R-B	4.2	NA	46.8	13.4	11.0	NA	NA	7.5	Chromite grains from A18R-A after crushing.
A19R	NA	<.0002	NA	NA	NA	<.001	<.001	NA	Peridotite grab sample with accessory chromite.
A20R-A	5.2	<.0001	29.7	10.6	11.1	<.001	<.001	NA	Hand-sorted coalescent chromite-bearing dunite.
A20R-B	4.5	NA	43.0	13.2	10.3	NA	NA	8.0	Chromite grains from A20R-A after crushing.
A21R-A	6.4	<.0001	32.0	10.5	13.1	<.001	<.001	NA	Hand-sorted massive chromite rubble from base of south-facing slope.
A21R-B	5.9	NA	44.8	12.6	11.1	NA	NA	7.0	Chromite grains from A31R-A after crushing.
A22R-A	9.5	<.0001	17.9	12.4	14.2	<.001	<.001	NA	Hand-sorted chromite-rich material from bands up to 2.5 in. thick.
A22R-B	9.4	NA	29.5	17.6	10.8	NA	NA	9.0	Chromite grains from A21R-A after crushing.
A23R	1.6	.002	9.7	7.9	24.4	<.002	<.004	NA	Hand-sorted chromite-rich material from serpentinized dunite with disseminated and coalescent chromite.
A24R	5.5	<.002	35.0	11.1	9.5	<.002	<.004	NA	Hand-sorted chromite-rich material from irregular, discontinuous, massive segregations.
A25R	2.2	<.002	8.6	8.0	22.2	<.002	<.004	NA	Dunite grab sample with coarse coalescent chromite in dunite.
A26R	1.2	.002	7.9	6.3	24.5	.002	.014	NA	Do.
A27R	3.8	.002	31.1	9.2	11.5	<.002	<.004	NA	Hand-sorted chromite-rich dunite from stringer zone in which coalescent bands are up to 5 in. thick. 25-ft-wide portion of larger zone contains 6 to 8 pct chromite.
A28R	4.0	<.002	31.4	9.7	10.5	<.002	<.004	NA	Hand-sorted chromite-rich dunite from composite stringer zone with 5- to 15-ft-wide portions containing 10 to 15 pct chromite.
A29R-A	1.4	<.002	6.3	6.3	21.1	<.002	<.004	NA	Representative sample across two 5- by 25-ft-wide banded zones containing 8 to 10 pct chromite.

TABLE 4. - Analytical results and descriptions of rock samples from the Avan Hills - continued

Sample	Al (pct)	Au (oz/st)	Cr (pct)	Fe (pct)	Mg (pct)	Pd (oz/st)	Pt (oz/st)	Si (pct)	Description
A29R-B	5.9	NA	23.0	10.2	10.2	NA	NA	NA	Hand-sorted chromite-rich dunite from same area as A28R-A.
A30R-A	NA	<.002	NA	NA	NA	<.002	<.004	NA	Representative sample from 55- by 100-ft stringer zone.
A30R-B	3.9	<.002	21.9	8.0	9.8	<.002	<.004	NA	Hand-sorted, banded, chromite-rich dunite from stringer zone described in A30R-A.
A31R-A	5.5	<.0001	29.4	9.5	11.7	<.001	<.001	NA	Hand-sorted massive chromite in rubble.
A31R-B	4.7	NA	42.8	12.6	10.7	NA	NA	9.5	Chromite grains from A30R-A after crushing.
A33R-A	9.4	<.0001	15.6	17.6	10.9	<.001	<.001	NA	Grab sample of massive chromite.
A33R-B	9.4	NA	28.1	26.3	8.8	NA	NA	7.5	Chromite grains from A33R-A after crushing.
A35R-A	13.6	<.0001	16.9	21.9	8.4	<.001	<.001	NA	Massive chromite in dunite boulders.
A35R-B	10.8	NA	23.8	32.9	7.2	NA	NA	3.5	Chromite grains from A35R-A after crushing.
A36R-A	6.9	<.0001	29.4	11.1	10.9	<.001	<.001	NA	Hand-sorted massive chromite in dunite.
A36R-B	5.6	NA	40.9	15.0	9.8	NA	NA	7.0	Chromite grains from A36R-A after crushing.
A38R	NA	<.0002	NA	NA	NA	<.001	<.001	NA	Brick-red, iron-stained, altered diabase.
A39R	NA	<.0002	NA	NA	NA	<.001	.002	NA	Grab sample of banded chromite in dunite.
A40R	NA	<.0002	NA	NA	NA	<.001	<.001	NA	Grab sample of dunite with disseminated chromite.
A41R-A	8.4	<.0001	27.9	10.8	9.7	<.001	<.001	NA	Hand-sorted chromite-rich dunite rubble.
A41R-B	7.3	NA	41.7	14.6	9.0	NA	NA	6.0	Chromite grains from crushed A41R-A.
A42R-A	5.4	<.0001	18.8	9.1	13.5	<.001	<.001	NA	Hand-sorted chromite-rich bands in dunite.
A42R-B	5.3	NA	29.2	12.7	12.0	NA	NA	14.5	Chromite grains from crushed A42R-A.
A43R	NA	.004	NA	NA	NA	<.001	<.001	NA	Grab sample of serpentinized peridotite.
A44R	NA	<.0002	NA	NA	NA	<.001	<.001	NA	Grab sample of altered gabbro.

TABLE 4. - Analytical results and descriptions of rock samples from the Avan Hills - continued

Sample	Al (pct)	Au (oz/st)	Cr (pct)	Fe (pct)	Mg (pct)	Pd (oz/st)	Pt (oz/st)	Si (pct)	Description
A47R	NA	<.0002	NA	NA	NA	<.001	<.001	NA	Red iron-stained gabbro with accessory pyrrhotite.
A48R	NA	<.0002	NA	NA	NA	<.0003	<.0003	NA	Altered gabbro.
A49R	NA	<.0002	NA	NA	NA	<.0003	<.0003	NA	Altered diabase.
A50R	NA	<.0002	NA	NA	NA	<.0003	<.0003	NA	Green chert.
A51R-A	NA	<.0002	NA	NA	NA	<.0003	<.0003	NA	Altered, magnetite-bearing gabbro.
A51R-B	NA	<.0002	NA	NA	NA	<.0003	<.0003	NA	Do.

NA Not analyzed.
NC Not calculated.
[1]Au, Pd, and Pt were preconcentrated by fire-assay and analyzed by atomic absorption by Bondar-Clegg, Inc., Lakewood, CO. Remaining elements analyzed by Bureau of Mines Reno (NV) Research Center using inductively coupled plasma procedures.

vertically. Individual chromite bands typically pinch out within 10 to 50 ft along strike. The chromite-bearing zone at sample location A27R is well exposed in a steep, north-facing slope, where a minimum down-dip extent of 35 ft was measured. The grade and width of this zone increased for a total of 110 ft along strike to the southeast, to a point where the zone is covered by dunite and peridotite talus. At the

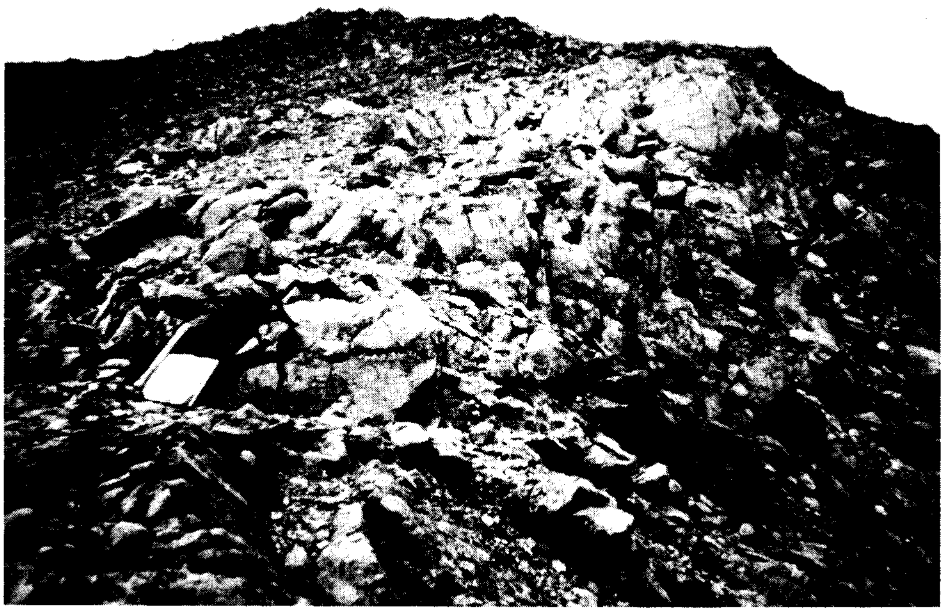


Figure 14. - Photograph of chromite stringer zone at deposit 12 in the Avan Hills.

southeast end of this zone, bands of coalescent chromite up to 5 in. wide were observed in a 35-ft^2-area (fig. 15). The overall grade of the zone is estimated at 8 pct chromite. At location A28R (deposit 17), a similar 175-ft-wide zone containing about 5 pct chromite is exposed for 300 ft along strike. Similar, but less well-exposed occurrences were observed at several locations along the ridge south of deposit 17 and were sampled at locations A29R and A30R(M) (fig. 12). Banded chromite is abundant in a 150-ft-wide zone in angular dunite rubble and talus for 1,500 ft downslope and southwest of deposit 19 as shown in figure 12. Based on these observations, this zone is estimated to contain between 261,000 and 522,000 st Cr_2O_3.

The greatest concentration of chromite observed in the entire western Brooks Range was discovered at deposit 7 in 1989 (figs. 12, 16, and 17). Like many of the other stringer zone deposits, this one contains chromite schlieren and banded layers of disseminated, coalescent, and massive chromite in dunite in outcrop, rubblecrop, and periglacially-transported regolith. Chromite-rich bands alternate with relatively barren dunite layers that contain about 1 pct disseminated chromite. In outcrop and in large rubble blocks at the margins of the chromite zone, wavy chromite schlieren are more abundant than are continuous layers or bands. The deposit was covered by snow at its southwestern end at the time of its discovery, has a maximum width of over 200 ft, averages about 150 ft wide, and was exposed for 1,060 ft along its strike length. This deposit is not only larger, but with between 5 and 10 pct chromite, is of higher grade than most of the other banded stringer zones described in this report. With minimum and maximum strike lengths of 1,060 ft and 1,325 ft, respectively, from 130,000 to 816,000 st Cr_2O_3 are estimated in this deposit (table B-2 in appendix B).

Results of preliminary gravity concentration tests at SLRC on samples collected along the five sample lines shown in figure 17 indicate that high-chromium concentrates are readily recoverable from deposit 7.

A third, less common type of chromite occurrence in the Avan Hills consists of coalescent and massive chromite nodules that make up 6 to 10 pct of the rock over areas measuring up to tens of feet across. At deposit 1, a 40-ft-long zone, ranging from 5 to 10 ft wide, contains banded segregations of nodular chromite (figs. 4 and 12). The elliptical chromite nodules average about 0.2 to 0.4 in. in maximum dimension and make up about 6 pct of the rock over measurable areas. At this location, the chromite is

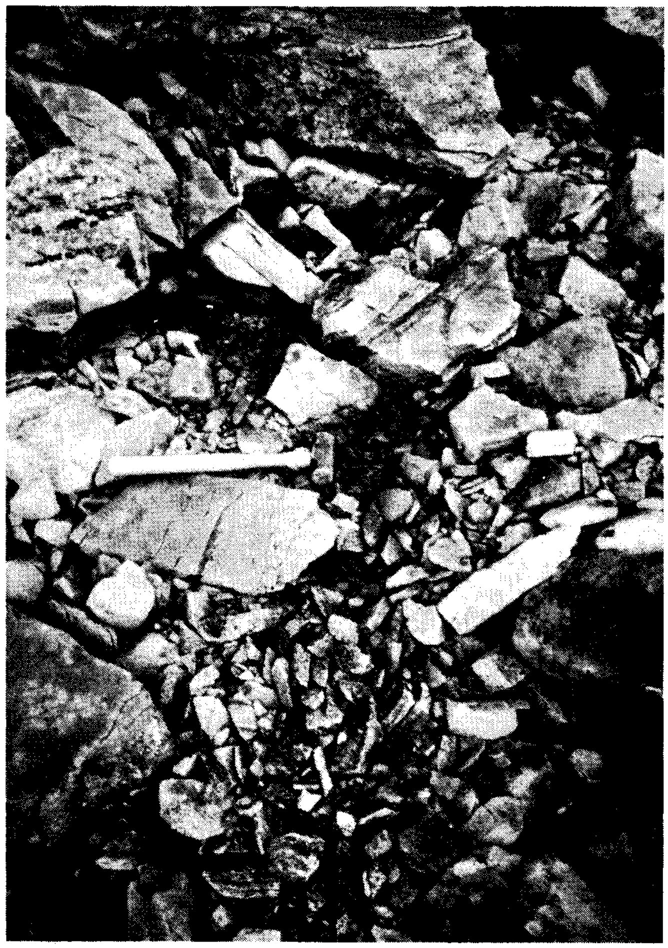


Figure 15. - Photograph of banded coalescent chromite in dunite rubble at the southeast end of deposit 12 in the Avan Hills.

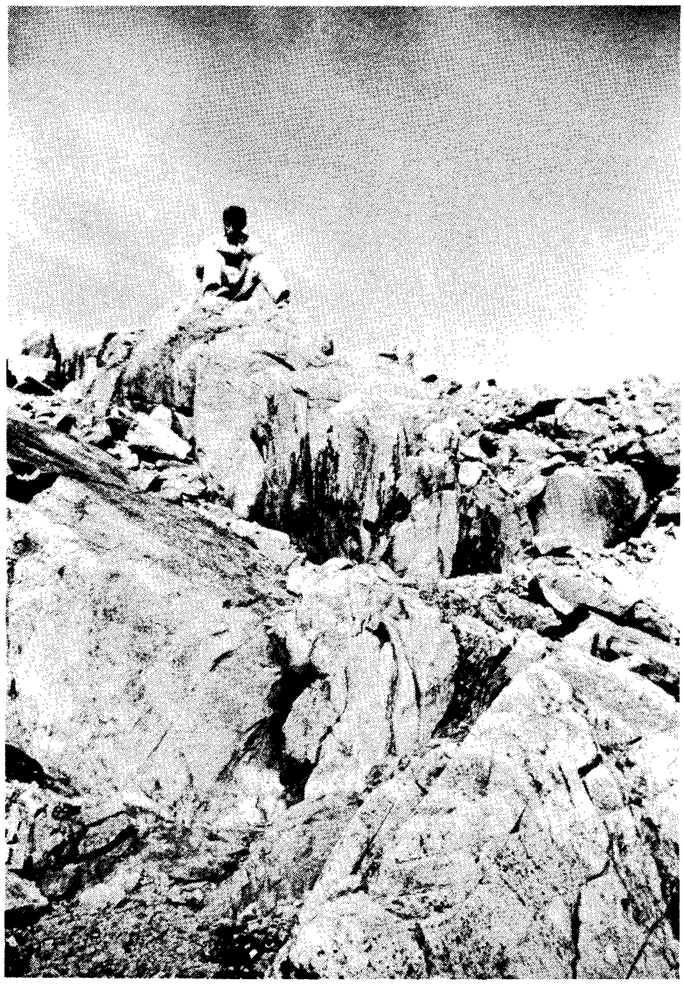


Figure 16. - Photograph of chromite schlieren and bands in outcrop and rubblecrop at southwest margin of deposit 7 in the Avan Hills.

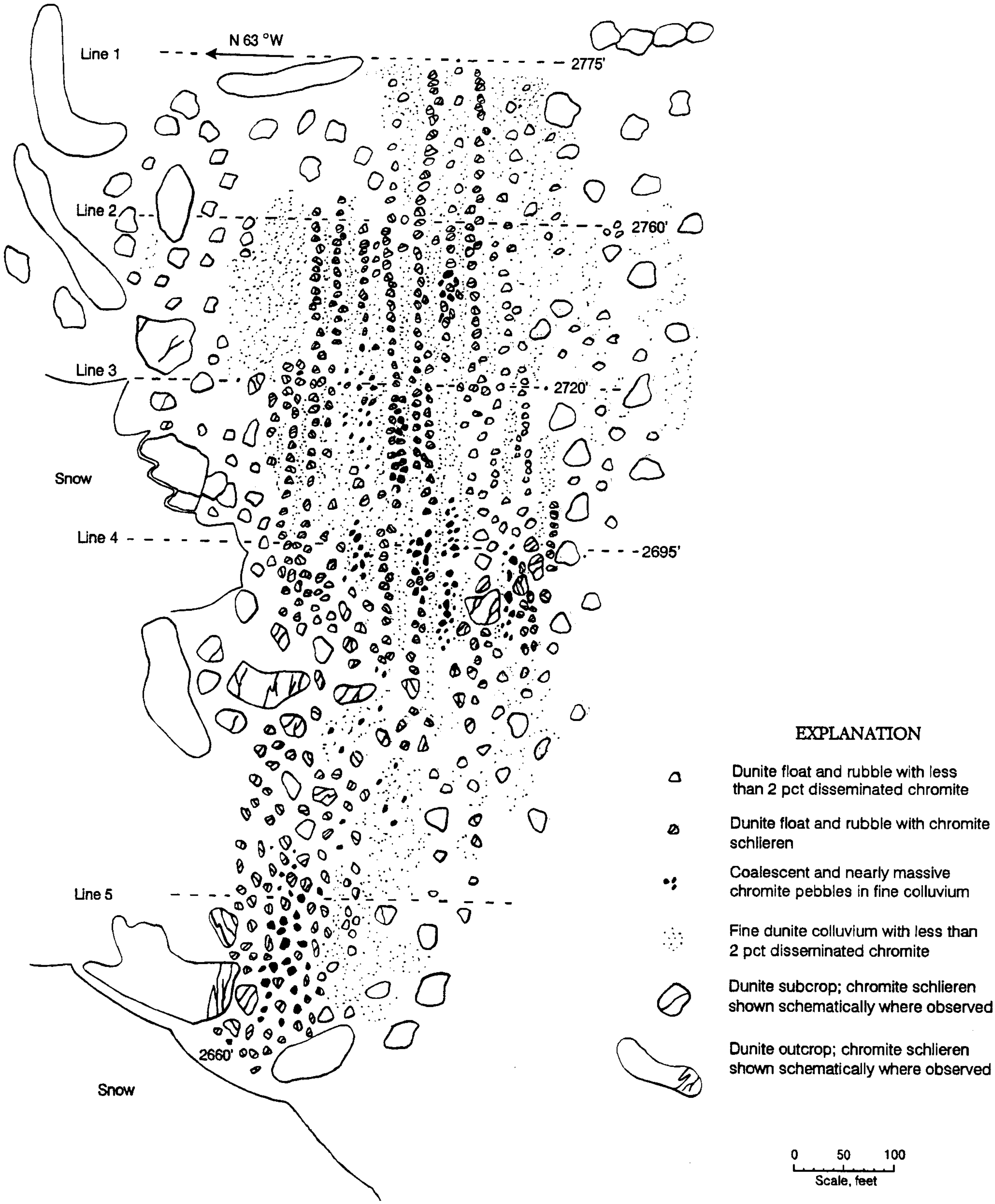


Figure 17. - Sketch map of large chromite stringer zone at deposit 7 in the Avan Hills.

in a dunite layer, bounded on either side by lherzolite. At deposit 2, a 23-ft by 55-ft, pear-shaped pod of dunite with 10 pct nodular chromite is exposed.

METALLURGICAL SAMPLE DESCRIPTIONS

Head analyses and estimated mineral compositions for bulk metallurgical samples from the Avan Hills are listed in table 5. Analytical results of tabled chromite concentrates listed in appendix C demonstrate that high-chromium concentrates can be produced from chromite in the Avan Hills.

Sample A5RM-A (14.3 lb) consists primarily of nearly massive, anhedral chromite. A few hand specimens exhibit nodular texture in which the chromite nodules are concentrated in a relatively chromite-free olivine matrix. On exposed surfaces, the chromite has weathered to a brownish-black and the chromite nodules stand out in relief. The nodules are 0.013 to 0.25 in. in cross section, slightly elongated, and closely spaced, less that 0.005 to 0.08 in. apart, in a matrix of weathered, pale yellow to orange serpentine. Fine, randomly oriented veinlets of pale green serpentine and lavender kammererite are evenly distributed throughout the more massive chromite. Minor relict olivine is present. Polished surface examination shows that both the massive and nodular chromite samples are highly fractured and sheared. Chromite liberation is complete at 65 mesh.

Sample A5RM-B (11 lb) consists of nodular chromite in which elongated nodules of chromite are evenly distributed in a matrix of serpentine minerals. Chromite stands out in relief on weathered surfaces. The nodules range form 0.08 to 0.25 in. wide and are from 0.13 to 0.75 in. long. Small amounts of relict olivine, kammererite, an unidentified ferromagnesian silicate mineral, and an unidentified nickel-bearing sulfide mineral are also present in the sample. Polished surface examination shows that the rock is highly fractured and the nodules are extensively broken and sheared. Fractures are filled with a pale green serpentine mineral that also rims some of the chromite nodules. Chromite is liberated by grinding to 100 mesh.

Sample A24RM (24.2 lb) consists of coalescent to nearly massive, subhedral to anhedral chromite. Chromite grains are black, lustrous, exhibit little evidence of alteration, and stand out in relief on weathered surfaces. This sample includes specimens with scattered nodules and clots of highly serpentinized olivine. Chromite grains average 0.02 to 0.05 in. across. Fine veinlets of buff-colored serpentine fill fractures and interstices between chromite grains. Traces of a nickel-bearing sulfide mineral, kammererite, and ferromagnesian silicate minerals are evenly disseminated throughout the sample. Examination of polished surfaces indicates that a moderate degree of fracturing has occurred on an intergranular level. Chromite is liberated by grinding to 35 mesh.

Samples A30RM-A (9.9 lb) and A30RM-B consist of planar bands of closely disseminated to coalescent, euhedral to subhedral chromite grains in a serpentinized olivine matrix. The chromite grains stand out in relief on weathered surfaces, are black and lustrous, and show no apparent effect of weathering. The chromite bands alternate with planar bands of chromite-free serpentinized olivine. The chromite-rich bands range from 0.02 to 0.05 in. wide and olivine bands are 0.08 to 0.38 in. wide. Larger chromite crystals, with diameters up to 0.02 in, are concentrated in the wider chromite bands. Polished section examination shows that the chromite is only slightly fractured, and fractures are filled with pale green serpentine. The chromite is liberated by grinding to 65 mesh.

TABLE 5. - Analytical results and mineral composition of bulk metallurgical samples from the Avan Hills

	A5RM-A	A5RM-B	A24RM	A30RM-A	A30RM-B
Analytical results:					
Cr_2O_3 (pct)	48.1	24.4	54.5	12.6	40.8
Fe (pct)	10.6	7.8	13.0	8.3	11.3
Al_2O_3 (pct)	10.8	5.7	10.2	3.2	9.6
MgO (pct)	17.6	28.4	16.0	39.8	23.0
SiO_2 (pct)	6.1	21.7	2.0	30.9	11.2
Au (oz/st)	<.002	<.002	<.002	<.002	<.002
Pd (oz/st)	<.003	<.003	.006	<.003	<.003
Pt (oz/st)	<.003	<.003	<.004	<.003	<.003
Mineral composition (wt pct):					
Chromite	81	39	91	23	77
Olivine	Tr	1	Tr	68	22
Serpentine	16	60	9	5	6
Magnetics[1]	ND	ND	ND	Tr	2
Chlorite[2]	3	Tr	Tr	Tr	Tr
Sulfide	Tr	Tr	Tr	Tr	Tr
Fe-Mg silicate	ND	Tr	Tr	4	3
Weight (lb)	14.3	11.0	24.2	9.9	19.8

ND Not detected.
Tr Trace.
[1] Minerals separated with hand magnet.
[2] Mineralogical variety kammererite.
Au, Pd, and Pt by fire-assay, atomic absorption at Bureau of Mines Reno Research Center, Reno, NV. Remaining elements analyzed by atomic absorption at Bureau of Mines Albany Research Center, Albany, OR.

RESULTS OF PLATINUM-GROUP METAL AND GOLD ANALYSES

Trace to anomalous concentrations of gold, iridium, palladium, and platinum were detected in rock and bulk metallurgical samples from the Avan Hills (table 4 and appendix C). Five chromite-bearing rock samples (A8R-A, A10R, A23R, A26R, and A27R) contain 0.002 oz/st Au and a serpentinized peridotite sample (A43R) contains 0.004 oz/st Au. Sample A26R also contains 0.002 oz/st Pd and 0.014 oz/st Pt. A minus 28- plus 65-mesh tabled concentrate from bulk metallurgical sample A5RM-B contains 0.016 oz/st Pd and the minus 65-mesh rougher tabled concentrate from the same sample contains 0.024 oz/st Au. No gold or PGM minerals were identified during microscopic examination of specimens from the Avan Hills.

Mowatt and Jansons (17) and Mowatt (18,19) report anomalous gold and PGM concentrations in iron- and iron-copper-sulfide-bearing gabbro and troctolite in the Avan Hills. Reported values for eight sulfide-bearing rock samples are: 110-360 ppb (0.003-0.011 oz/st) Au; 412-990 ppb (0.012-0.029 oz/st) Pd; 606-1,502 ppb (0.018-0.044 oz/st) Pt; 1,100-3,500 ppm Cu, 60-410 ppm Ni; and 19-61 ppm Co (19). No locations are provided for the anomalous samples.

PLACER INVESTIGATION

Analytical data for pan concentrate samples collected during the 1982 and 1983 Bureau of Mines investigations (table 6) indicate that chromite and traces of PGM are present in alluvium along the Avan River and tributaries of the Kelly River. Alluvial deposits up to one mile wide that possibly contain recoverable chromite occur along these broad glacial valleys (fig. 18). Pan concentrate samples collected downstream from dunitic portions of the Avan Hills mafic-ultramafic complex contain from 2.7 to 24.0 pct Cr, indicating that chromite is abundantly present and can be recovered by gravity procedures.

Nonmagnetic and magnetic fractions from pan concentrates collected by the USGS during separate studies were donated to the Bureau for chromium, gold, and PGM analysis. Nonmagnetic fractions for two samples from the Avan River Valley contain 11.6 and 24.3 pct Cr with no significant PGM. One of the two samples contains 131 ppb (0.004 oz/st) Au. Platinum and palladium in the magnetic fractions from these samples are slightly enriched compared to the nonmagnetic fractions.

TABLE 6. - Analytical results for pan concentrate samples from the Avan Hills[1]

Sample	Au (oz/st)	Cr (pct)	Ir (oz/st)	Os (oz/st)	Pd (oz/st)	Pt (oz/st)	Rh (oz/st)	Ru (oz/st)
A1P	<0.0002	2.7	NA	NA	<0.002	<0.002	NA	NA
A2P	<.0002	4.8	NA	NA	<.002	<.002	NA	NA
A4P	<.0002	NA	NA	NA	<.002	<.002	NA	NA
A32P	<.0002	NA	ND	ND	<.001	<.001	ND	ND
A34P	<.0002	24.0	ND	ND	<.0003	<.0003	ND	ND
A37P-A	<.0002	NA	0.0036	ND	<.0003	<.0003	ND	ND
A37P-B	<.0002	NA	NA	ND	.0003	.002	ND	ND
A45P	<.0002	NA	NA	ND	<.0003	<.0003	ND	ND
A46P	<.0002	NA	NA	ND	<.0003	<.0003	ND	ND
A52P	<.0002	NA	NA	NA	<.0003	<.0003	NA	NA
A53P	<.0002	NA	NA	ND	<.001	<.001	ND	ND

NA Not analyzed
ND Not detected
[1] Analyses by Bondar-Clegg Inc., Lakewood, CO. Cr analyzed by atomic absorption after peroxide fusion. Au, Pd, and Pt preconcentrated by fire-assay and analyzed by atomic absorption. Ir, Os, Rh, and Ru analyzed by fire-assay, emission spectrography by Bureau of Mines Reno Research Center, Reno, NV.

Figure 18. - Photograph of broad glacial valley along the upper Avan River.

ASIK MOUNTAIN

No chromite resource estimates are available for chromite occurrences at Asik Mountain. The Bureau did not investigate Asik Mountain, but two chromite occurrences there are described by Saunders (28). Saunders collected two samples that contained 6.6 and 5.6 pct Cr from two 1- to 2-in.-thick parallel bands of chromite in basic igneous rock at the 1,000-ft elevation, west of the Agashashok River. A similar occurrence 0.5 mile southwest of the sampled occurrence was also reported but was not sampled.

Mowatt (19) reports anomalous gold and PGM concentrations in iron- and iron-copper-sulfide-bearing gabbro and troctolite(?) at Asik Mountain. Reported values for six sulfide-bearing rock samples are: 80-220 ppb (0.002-0.006 oz/st) Au; 480-1,112 ppb (0.014-0.033 oz/st) Pd; 510-1,605 ppb (0.015-0.047 oz/st) Pt; 1,100-3,600 ppm Cu, 110-655 ppm Ni; and 80-125 ppm Co (19). No locations are provided for these samples.

MISHEGUK MOUNTAIN

CHROMITE DEPOSITS

Estimated chromite resources for nine deposits at Misheguk Mountain are between 121,000 and 361,000 st Cr_2O_3. Dimensions, grade, tonnage estimates, and deposit descriptions are listed in table B-3 in appendix B. The bulk of the chromite resources at Misheguk Mountain are contained in one deposit; the remaining eight each contain between 70 st and 33,000 st Cr_2O_3. Deposits at Misheguk Mountain are similar to low-grade banded stringer zones in the Avan Hills, with grades ranging from 3 to 6 pct chromite. Additional buried lode and placer deposits may be present in the area.

Misheguk Mountain (fig. 1) is separated from the Avan Hills by the Kugururok River and Trail Creek Valleys, a distance of about 12 miles. The two areas are physiographically very similar.

Bureau personnel spent five days at Misheguk Mountain in 1983. Four additional days were spent working in the area in 1989 by a combined Bureau, USGS, ADGGS, and West Virginia University team. Analytical results and descriptions of rock samples collected in the period from 1981 through 1983 are listed in table 7. Figure 19 shows geology, sample locations, and chromite occurrences in the 35 mi^2 portion of the complex investigated by the Bureau.

Rock types observed in the Misheguk Mountain area are essentially the same as those in the Avan Hills complex, but the proportions of the rocks are radically different. Cumulate gabbroic rocks make up over three-fourths of the 120 mi^2 Misheguk Mountain mafic-ultramafic complex. Contacts between the cumulate gabbroic rocks and the cumulate and tectonized ultramafic rocks are gradational over a transition zone that is several thousand feet thick.

Chromite occurs in orange-brown weathering dunite and red-brown-weathering peridotite at Misheguk Mountain. Banded chromite occurrences at Misheguk Mountain are similar to banded occurrences in the Avan Hills. An irregularly shaped mass of high-iron chromite with associated PGM is described in the following section titled "Results of Platinum-Group Metal and Gold Analyses".

The largest concentration of chromite observed at Misheguk Mountain is at deposit 2 (fig. 19), where abundant banded chromite was observed at the 3,600-ft elevation. In this area, a 300- by 750-ft zone strikes about N 50° E along the base of a cirque and contains individual bands of massive and coalescent chromite up to 10 in. thick. The deposit is estimated to contain between 78,000 and 261,000 st Cr_2O_3;

TABLE 7. - Analytical results and descriptions of rock samples from Misheguk Mountain[1]

Sample	Al (pct)	Au (oz/st)	Cr (pct)	Fe (pct)	Mg (pct)	Pd (oz/st)	Pt (oz/st)	Description
MIR	4.1	<0.002	27.5	9.2	13.4	<0.002	<0.004	Grab sample of massive chromite float from creek bed.
M2R-A	1.9	.004	10.4	7.6	20.1	.003	<.004	Composite grab sample from frost boils containing dunite with banded chromite.
M2R-B	2.4	<.002	23.3	8.4	16.1	<.002	<.004	Hand-sorted chromite-rich material from frost boils. Same location as M2R-A.
M3R-A	5.3	.002	10.5	9.2	19.3	<.002	<.004	Hand-sorted chromite-rich dunite from outcrop with discontinuous chromite bands and schlieren.
M3R-B	.2	<.002	.3	6.1	26.0	<.002	<.004	Chip sample from outcrop at M3R.
M5R	3.6	<.002	18.9	8.9	16.4	<.002	<.004	Hand-sorted chromite-rich bands in dunite.
M6R	6.6	<.002	<.1	10.1	3.1	<.002	<.004	Grab sample of granulated and altered metamorphic rock with accessory pyrrhotite.
M10R	3.3	<.002	12.0	6.8	17.8	<.002	<.004	Hand-sorted banded chromite segregations from rubble at base of cirque.
M11R-A	6.6	<.002	21.4	9.2	16.3	<.002	<.004	Hand-sorted chromite bands in dunite rubble and bedrock.
M11R-B	.3	<.002	.8	7.1	28.5	<.002	<.004	Chip sample from dunite with disseminated chromite at same location as M11R-A.
M14R	4.5	<.002	.1	8.7	12.5	.004	.005	Grab sample of serpentinized plagioclase peridotite with accessory pyrrhotite.
M15R	9.2	<.002	<.1	4.6	5.4	<.002	<.004	Grab sample of red-brown, iron-stained, medium-grained, olivine gabbro with accessory chalcopyrite.
M17R	6.9	<.002	0.2	12.1	4.3	<.002	<.004	Grab sample of red-weathering gabbro with accessory chalcopyrite.
M21R	8.3	.002	<.1	5.6	4.1	<.002	<.004	Grab sample of very coarse-grained olivine gabbro with accessory pyrrhotite.
M24R-A	0.1	<.002	.5	6.5	23.5	.002	<.004	Chip sample collected from dunite rubble containing coarse-grained disseminated chromite.

Sample	Al (pct)	Au (oz/st)	Cr (pct)	Fe (pct)	Mg (pct)	Pd (oz/st)	Pt (oz/st)	Description
M24R-B	.3	<.002	2.2	6.2	22.0	<.002	.004	Hand-sorted dunite with coarse chromite grains from same location as M24R-A.
M25R	.2	<.002	1.9	6.0	26.4	<.002	<.004	Composite grab sample from dunite rubble containing coarse-grained disseminated chromite and chromite bands.
M27R	4.0	<.002	15.4	9.0	16.0	<.002	<.004	Hand-sorted chromite-rich bands in dunite.
M28R-A	.7	<.002	2.6	7.2	23.1	<.002	<.004	Grab sample of dunite with wispy segregations of coarse-grained chromite.
M28R-B	.2	.002	.4	6.8	25.4	<.002	<.004	Chip sample from same location as M28R-A.
M28R-C	5.9	<.002	28.2	10.8	10.5	<.002	<.004	Hand-sorted chromite-rich bands in dunite rubble.
M29R	2.3	<.002	12.5	5.7	19.6	<.002	<.004	Grab sample of banded chromite in dunite.
M30R	10.6	<.002	9.8	15.8	14.1	<.002	.004	Grab sample of dunite with 1-in-thick band of coalescent chromite.

[1]Au, Pd, and Pt were preconcentrated by fire-assay and analyzed by atomic absorption by Bonder-Clegg, Inc., Lakewood, CO. Remaining elements analyzed by Bureau's Reno (NV) Research Center using inductively coupled plasma techniques.

the widespread abundance of banded chromite talus and rubble at the base of the cirque (fig. 20) indicates that a much larger zone possibly exists.

Other low-grade banded zones with significant identified chromium resources were measured at deposits 1,3,4,5,6, and 8 (table B-3, appendix B).

Figure 20. Photograph of banded and massive chromite in dunite talus at base of cirque, deposit 2, Misheguk Mountain.

METALLURGICAL SAMPLE DESCRIPTIONS

Analytical results and estimated mineral compositions for bulk metallurgical samples from Misheguk Mountain are listed in table 8.

Sample M10RM (13.2 lb) consists of 0.05- to 0.25-in.-wide planar bands of closely disseminated to coalescent chromite in an extensively serpentinized olivine matrix. The planar chromite bands alternate with relatively chromite-free bands of serpentinized olivine that range in width from 0.05 to 0.75 in. The bands exhibit some rippling due to offset fracturing of the rock. The chromite is subhedral, subresinous, and black. Olivine grains within the wider olivine bands are less serpentinized than olivine that is adjacent to chromite grains. The chromite grains are unaltered on exposed surfaces and stand out slightly against the weathered olivine matrix, giving the rock a rough surface texture. The buff-colored weathering rind averages 0.12 to 0.25 in. thick.

TABLE 8. - Analytical results and mineral composition of bulk metallurgical samples from Misheguk Mountain

	M10RM	M26RM
Analytical results:		
Cr_2O_3 (pct)	20.2	47.6
Fe (pct)	8.2	11.8
Al_2O_3 (pct)	5.9	13.0
MgO (pct)	33.3	18.5
SiO_2 (pct)	23.0	5.2
Au (oz/st)	<0.002	<0.002
Pd (oz/st)	.047	<.003
Pt (oz/st)	<.003	<.003
Mineral composition (wt pct):		
Chromite	37	88
Olivine	49	2
Serpentine	12	9
Magnetics[1]	Tr	1
Chlorite[2]	Tr	Tr
Sulfides	Tr	ND
Fe-Mg silicates	2	ND
Weight (lb)	13.2	61.6

ND Not detected.
Tr Trace.
[1] Minerals separated with hand magnet.
[2] Mineralogical variety kammererite.
Au, Pd, and Pt analyzed by fire-assay, atomic absorption at Bureau of Mines Reno Research Center, Reno, NV. Remaining elements analyzed by atomic absorption at Bureau of Mines Albany Research Center, Albany, OR.

Polished section examination shows that the rock is extensively fractured and sheared, and that individual chromite crystals are crossed by a network of serpentine-filled microfractures. The chromite is liberated by grinding to 65 mesh.

Sample M26RM (61.6 lb) consists of nearly massive, extensively fractured chromite. Minor pale-colored serpentine and olivine fill fractures and interstices. Traces of kammererite are also present. Chromite is anhedral, black, and subvitreous. The rock is fractured and sheared with slickensides present on many surfaces. Polished section examination shows that individual chromite grains are also fractured. Chromite is liberated by grinding to 28 mesh.

RESULTS OF PLATINUM-GROUP METAL AND GOLD ANALYSES

Trace to anomalous concentrations of PGM and gold were detected in rock and bulk metallurgical samples from several sites at Misheguk Mountain. Numerous rock samples, including chromite-bearing dunites and sulfide-bearing plagioclase peridotite contain between 0.002 and 0.005 oz/st Au, Pd, and Pt (table 7).

Higher concentrations of gold and palladium were detected in bulk metallurgical sample M10RM. The sample heads contain 0.047 oz/st Pd and the 28- by 65-mesh tabled concentrate contain 0.028 oz/st Au (table 8 and appendix C).

As much as 0.27 oz/st combined PGM were detected by the Bureau in replicate samples collected by R.A. Harris[8] from a chromite pod at Misheguk Mountain (figs. 21-23). The chromite at this location is anomalously high in iron content, with a Cr-Fe ratio of 1.3:1. Scanning-electron microscopic examination detected minute sperrylite ($PtAs_2$) and argentite inclusions in the chromite from this location. An olivine clinopyroxenite sample with accessory iron-sulfide minerals collected adjacent to the chromite pod in 1989 contains 0.006 oz/st combined Pt+Pd (120 ppb Pt and 100 ppb Pd).

Elevated PGM concentrations were also detected in 1989 in other rock samples from Misheguk Mountain. These included 0.007 oz/st Pt+Pd (150 ppb Pt and 96 ppb Pd) in wehrlite, 0.011 oz/st Pt+Pd (150 ppb Pt and 230 ppb Pd) in dunite with accessory chromite, and 0.010 oz/st Pt+Pd (130 ppb Pt and 210 ppb Pd) in altered gabbro samples.

Mowatt and Jansons (17) and Mowatt (18,19) report anomalous gold and PGM concentrations in iron- and iron-copper-sulfide-bearing gabbro and troctolite(?) at Misheguk Mountain. Reported values for six sulfide-bearing rock samples are: 100-250 ppb (0.003-0.007 oz/st) Au; 402-985 ppb (0.012-0.029 oz/st) Pd; 512-1,826 ppb (0.015-0.053 oz/st) Pt; 1,500-4,000 ppm Cu, 115-808 ppm Ni; and 30-82 ppm Co (19). No sample locations are provided by the earlier workers.

PLACER INVESTIGATIONS

Pan concentrate samples collected from streams that drain the dunitic portions of Misheguk Mountain contain abundant chromite and have chromium contents ranging up to 18.4 pct (table 9). These data indicate that chromite is present in the streams and may be recovered by gravity concentration procedures. Gold values ranging from 0.002 oz/st to 0.031 oz/st were detected in pan concentrate samples (M7P, M8P, M9P, M18P, M19P, and M22P, table 9) from Misheguk Mountain.

---

[8] Assistant Professor of Geology, West Virginia University, Morgantown, WV.

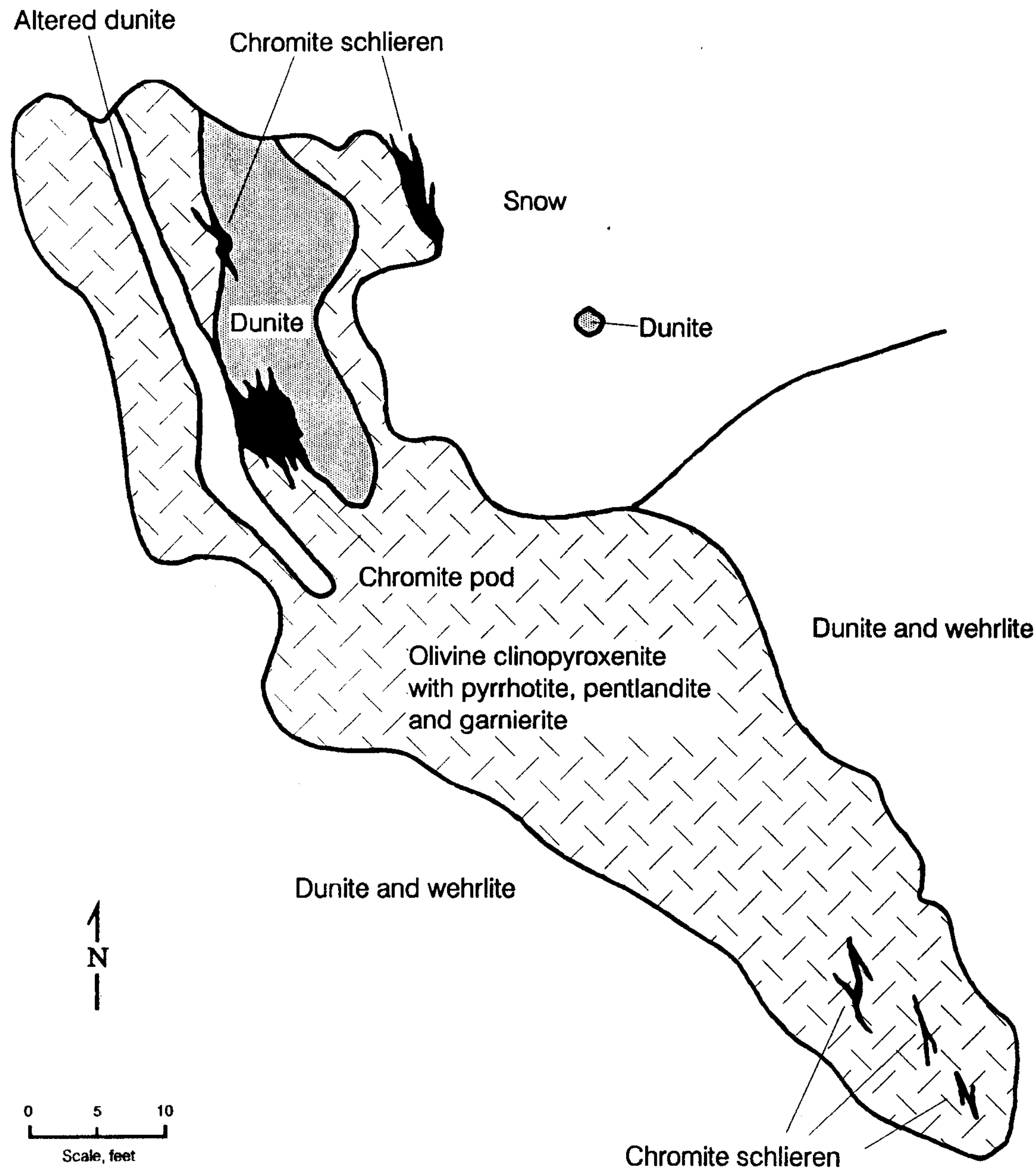


Figure 21. - Sketch map of PGM-chromite occurrence at Misheguk Mountain.

Figure 22. - Photograph of PGM-chromite occurrence in dunite and clinopyroxenite outcrop and rubblecrop at Misheguk Mountain.

Figure 23. - Closeup photograph of PGM-bearing iron-rich chromite pod in dunite at Misheguk Mountain.

TABLE 9. - Analytical results for pan concentrate samples from Misheguk Mountain[1]

Sample	Au (oz/st)	Cr (pct)	Pd (oz/st)	Pt (oz/st)
M4P	<0.002	5.8	<0.002	<0.002
M7P	.031	6.1	<.002	<.002
M8P	.003	3.1	<.002	<.002
M9P	.002	6.6	<.002	<.002
M12P	<.002	.2	<.002	<.002
M13P	<.002	.3	<.002	<.002
M16P	<.002	1.2	<.002	<.002
M18P	.012	.6	<.002	<.002
M19P	.002	5.7	<.002	<.002
M20P	<.002	.1	<.002	<.002
M22P	.003	.4	<.002	<.002
M23P	<.002	18.4	<.002	<.002

[1]Analyses by Bondar-Clegg Inc., Lakewood, CO. Cr analyzed by atomic absorption after peroxide fusion. Au, Pd, and Pt preconcentrated by fire-assay and analyzed by atomic absorption.

SINIKTANNEYAK MOUNTAIN

CHROMITE DEPOSITS

Chromite deposits similar to those at the other sites in the western Brooks Range were observed at Siniktanneyak Mountain in 1991 (fig. 24). Chromite schlieren, and banded and massive chromite segregations (figs. 25 and 26) are discontinuously exposed in areas measuring thousands of feet in strike length by hundreds of feet in width. Because the chromite segregations are highly variable in grade and extent within the larger zones, no chromite resource estimates were calculated. These chromite deposits were identified in the southernmost of two areas at Siniktanneyak Mountain that are underlain by dunite and peridotite (fig. 24). The northernmost of the two dunite-peridotite areas was not traversed. This area probably contains additional chromite.

Siniktanneyak Mountain (fig. 1) is the most remote of all the areas described in this report. It lies east of the De Long Mountains at the crest of the Brooks Range, about 150 miles northeast of Kotzebue. The mountain reaches almost 5,000 ft in elevation and has a maximum relief of over 3,000 ft. Moderate to steep, talus-covered slopes are typical, with outcrops restricted to stream cuts and the uppermost reaches of the mountain.

Figure 25. - Photograph of disseminated, coalescent, and massive chromite bands in dunite rubblecrop at Siniktanneyak Mountain.

Figure 26. - Photograph of parallel chromite bands exposed on weathered surface (top) and edges (sides) of dunite boulder in rubblecrop at Siniktanneyak Mountain.

The 70 mi^2 Siniktanneyak Mountain massif is mostly underlain by mafic rocks including cumulate gabbro and hornblende-pyroxene gabbro (22,23) (fig. 23). Ultramafic rocks, including orange-weathering dunite with associated wehrlite, harzburgite, and olivine pyroxenite, are largely restricted to a 10-mi^2 area in the southeastern portion of the complex (22). The dunite is reported to locally contain discontinuous layers, pods, and wispy stringers of chromite (16,22). A small outlier of ultramafic rocks that may also contain chromite lies about 3 miles southwest of Siniktanneyak Mountain, in the Avingyak Hills.

References to mineral deposits of unspecified commodities in mafic and ultramafic rocks at Siniktanneyak Mountain are contained in two earlier reports (1,2). Jansons and Baggs (16) describe a 8-in.-wide by 12-ft-long band of chromite at Siniktanneyak Mountain. Nelson and Nelson (22) also mention, but do not describe or give locations for chromite occurrences in ultramafic rocks at Siniktanneyak Mountain.

RESULTS OF PLATINUM-GROUP METAL AND GOLD ANALYSES

During the 1991 investigation, gold and anomalous gold and PGM were detected in a variety of lithologies. These data indicate that gold and PGM are likely to be present in native form or combined with other elements in metallic minerals that may be physically recoverable. The anomalous values are not of ore tenor but their existence indicates that mineralizing processes have occurred, thereby concentrating the precious metals above values observed in rocks containing only silicate gangue minerals. The highest concentrations of PGM were detected in two coarse-grained olivine clinopyroxenite dike samples that contain unusually coarse chromite crystals as much as 0.4 in. in maximum dimension.

These two samples contain 6 and 110 ppb Pd and 235 and 618 ppb Pt. Pyritic rhyolite(?) float collected at the base of a basaltic outcrop along the eastern slope of Siniktanneyak Mountain contains 18 ppb Au, 280 ppb Pd, and 65 ppb Pt. Gold and PGM were also detected in select samples of almost every mafic and ultramafic lithology described at Siniktanneyak Mountain. Chromitite samples and dunite samples with chromite contain as much as 19 ppb Au, 57 ppb Pd, and 172 ppb Pt. Gabbro samples with accessory sulfide minerals contain as much as 184 ppb Au, 14 ppb Pd, and 25 ppb Pt.

Nelson and Nelson (22) report detectable platinum (0.020-0.070 ppm Pt) in two ultramafic rock samples and detectable palladium (0.002-0.100 ppm Pd) in six ultramafic rock samples from Siniktanneyak Mountain.

Mowatt and Jansons (17) and Mowatt (18,19) report anomalous gold and PGM concentrations in iron- and iron-copper-sulfide-bearing troctolitic(?) gabbro at Siniktanneyak Mountain. Reported values for six sulfide-bearing rock samples are: 150-240 ppb (0.004-0.007 oz/st) Au; 511-1,426 ppb (0.015-0.042 oz/st) Pd; 483-1,215 ppb (0.014-0.035 oz/st) Pt; 1,000-2,600 ppm Cu, 230-910 ppm Ni; and 56-115 ppm Co (19). No sample locations are provided by the earlier workers.

PLACER INVESTIGATIONS

Gold (0.027 oz/st Au) was detected in a pan sample (S1P) collected by the Bureau at Siniktanneyak Mountain in 1981 (fig. 23). Anomalous gold and chromium concentrations were detected in pan concentrate samples collected by the USGS at Siniktanneyak Mountain and analyzed by Bondar-Clegg, Inc. for the Bureau of Mines. Pan concentrate samples collected by the USGS from six locations at Siniktanneyak Mountain contain from 0.05 to 14.8 pct Cr. One of these samples contains 336 ppb (0.010 oz/st) Au.

During the 1991 investigations, four additional pan concentrate samples were collected by the Bureau at Siniktanneyak Mountain. Maximum gold and PGM concentrations detected in these samples are 84 ppb Au, 4 ppb Pd, and 7 ppb Pt. Chromium values for these samples ranged from 403 ppm to 4.9 pct Cr.

BENEFICIATION PROCEDURE

Each of the bulk metallurgical samples from the western Brooks Range was crushed in a series of crushers to pass 0.25 in. Splits were prepared for head analyses and beneficiation tests. The procedure used to beneficiate each sample is shown in figure 27.

Minus 0.25-in. material was screened at 28 and 65 mesh. The plus 28-mesh fraction was ground dry in a minus 13- plus 25-in. rod mill or a minus 7- plus 9-in. rod mill to pass 28 mesh and sized at 65 mesh. Grinding was done in stages to minimize production of fines.

The 28- by 65-mesh fraction was tabled on the sand deck of a 2- by 4-ft laboratory shaking table to produce a clean concentrate and tailings. The tailings were dried and then stage-ground to minus 65 mesh to improve liberation. The ground product was then combined with the minus 65-mesh material from the initial grinding and tabled on a slime deck. A high-grade concentrate, middlings, coarse tailings (those that settled and banded on the table), and slime tailings (those that washed off the deck before they had a chance to settle) were collected. In some cases, samples were relatively high-grade and the amount of middlings and coarse tailings was small. Also, in some chromite-rich samples, substantial chromite was intermixed with coarse tailings in overlapping bands on the table. When conditions such

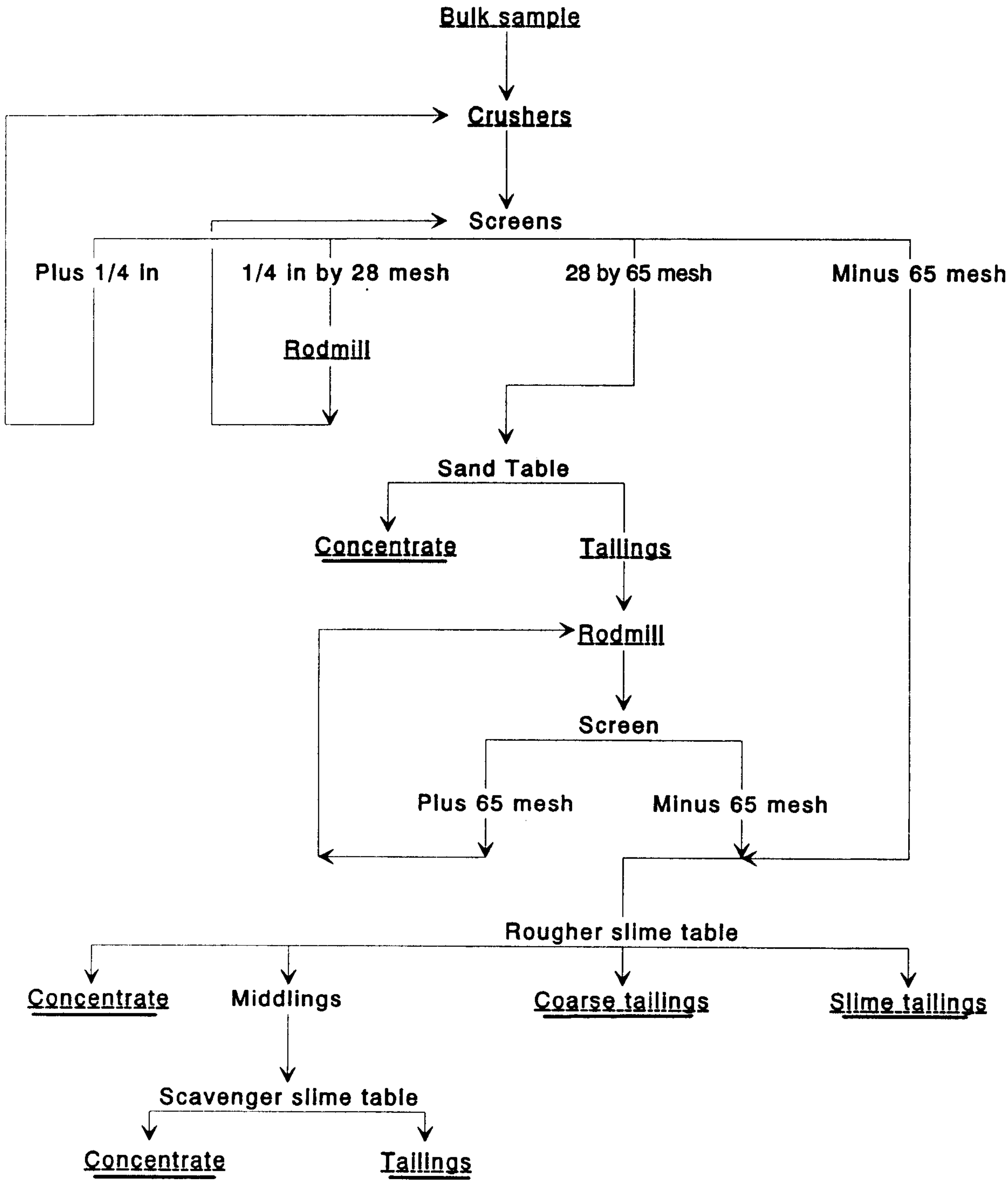


Figure 27. - Diagram of beneficiation procedure used to concentrate chromite.

as these prevented sharp separation, middlings and coarse tailings were collected as one product. To improve chromite recovery, a scavenger table operation was done on the rougher table middlings (or the middlings and coarse tailings combined product) to produce a scavenger concentrate and tailings.

BENEFICIATION RESULTS

Beneficiation results are summarized in tables 10 and 11 and in the individual metallurgical balances in appendix C. Composite chromite concentrates reported in the tables are mathematical combinations of the 28- by 65-mesh concentrate and minus 65-mesh rougher and scavenger concentrates.

All of the composite chromite concentrates may be classified as high-chromium (metallurgical-grade) chromite (minimum of 46 pct Cr_2O_3 with a Cr-Fe ratio greater than 2.0). The concentrate grades range from 49.0 to 59.5 pct Cr_2O_3 and the Cr-Fe ratios range from 2.3 to 3.3. Cr_2O_3 recoveries range from 72 to 99 pct.

Tailings products from the beneficiation procedure contained recoverable chromite. The coarse rougher tailings and scavenger tailings contained both interlocked chromite and liberated chromite. Further grinding could have liberated the interlocked chromite grains and improved recovery. Liberated chromite that was lost in the three tailings products could have been recovered by gravity separation techniques, such as flotation, that are better suited for fine particle recovery than tabling or possibly by high-intensity magnetic separation or electrodynamic separation.

TABLE 10. - Analytical results for high-purity chromite concentrates from western Brooks Range samples[1]

Sample	Analytical results (wt pct)					Cr-Fe ratio
	Cr_2O_3	Fe	MgO	Al_2O_3	SiO_2	
IYIKROK MOUNTAIN						
12RM	60.5	12.1	14.2	6.2	0.7	3.4
15RM	60.7	12.8	14.2	6.0	.9	3.2
16RM	57.6	12.7	13.8	8.9	.8	3.1
AVAN HILLS						
A5RM-A	54.1	11.3	15.5	11.1	1.5	3.3
A5RM-B	51.7	11.7	15.8	12.2	2.2	3.0
A24RM	55.1	12.9	15.2	8.8	.8	2.9
A30RM-A	51.9	14.4	14.8	10.6	.9	2.5
A30RM-B	54.8	13.4	15.9	8.6	.9	2.8
MISHEGUK MOUNTAIN						
M10RM	49.7	12.4	14.9	16.8	1.6	2.7
M26RM	51.9	11.7	16.4	14.7	1.3	3.0

[1] Analyses by atomic absorption at Bureau of Mines Abany Research Center, Albany, OR.

TABLE 11. - Analytical results for tabled chromite concentrates from deposits in the western Brooks Range[1]

Sample	Analytical results (wt pct)					Cr_2O_3 recovery (pct)	Cr-Fe ratio
	Cr_2O_3	Fe	MgO	Al_2O_3	SiO_2		
IYIKROK MOUNTAIN							
12RM	59.3	12.2	16.0	7.1	2.4	87.2	3.3
15RM	59.5	12.9	14.7	7.3	2.2	87.2	3.2
16RM	56.5	13.8	14.7	8.9	2.4	85.7	2.8
AVAN HILLS							
A5RM-A	52.7	11.7	15.0	12.4	2.0	93.4	3.1
A5RM-B	49.0	12.1	15.5	12.1	5.0	78.8	2.8
A24RM	55.5	13.5	12.6	11.0	.9	98.6	2.8
A30RM-A	49.1	14.7	15.6	12.1	3.8	83.4	2.3
A30RM-B	53.4	14.8	15.1	10.8	2.7	88.3	2.5
MISHEGUK MOUNTAIN							
M10RM	49.9	12.7	15.6	14.7	3.0	72.5	2.6
M26RM	51.0	11.4	16.1	14.2	2.5	95.3	3.1

[1] Analyses by atomic absorption at Bureau of Mines Albany Research Center, Albany, OR.

SUMMARY AND CONCLUSIONS

Chromite deposits in dunite and peridotite at Iyikrok Mountain, in the Avan Hills, and at Misheguk Mountain in northwestern Alaska contain total identified mineral resources of between 710,000 and 2,300,000 st Cr_2O_3. Additional resources exist in buried extensions of the known deposits, in undiscovered deposits, and in placer deposits in valleys adjacent to the chromite-bearing ultramafic rocks. Chromite is also reported at Asik Mountain and Siniktanneyak Mountain, but no resource estimates are available for these two locations. Total identified resources for two deposits at Iyikrok Mountain are between 144,000 and 383,000 st Cr_2O_3. The largest deposit there contains about 4 pct chromite, is intermittently exposed in a 500- by 1,000-ft zone, and is estimated to contain between 139,000 and 371,000 st Cr_2O_3. In the Avan Hills there are 59 deposits that contain a total of between 446,000 and 1,550,000 st Cr_2O_3. Deposits in the Avan Hills comprise segregations of massive chromite and larger stringer zones that range from tens to hundreds of feet wide by hundreds to over one thousand feet long and contain from 3 to 10 pct chromite. The largest of the stringer zone deposits is estimated to contain between 130,000 and 816,000 st Cr_2O_3. The larger deposits comprise chromite schlieren and disseminated, coalescent, and massive chromite in multiple parallel chromite bands. At Misheguk Mountain, one large banded chromite deposit, containing from 78,000 to 261,000 st Cr_2O_3, and 8 smaller banded deposits contain a total of between 121,000 and 361,000 st Cr_2O_3.

Metallurgical tests on 10 bulk samples collected from eight deposits indicate that high-chromium concentrates suitable for use by the metallurgical industry are recoverable. Two of the samples were collected at Iyikrok Mountain, five at the Avan Hills, and three from Misheguk Mountain. Geochemical analyses on additional samples from other deposits and occurrences indicate that high-chromium chromite is widespread in the three areas.

Potential exists for placer and lode PGM and gold deposits in the western Brooks Range. Anomalous gold and PGM were detected in chromite samples and tabled chromite concentrates and in most of the other lithologies present in the mafic ultramafic portions of the ophiolites. Sperrylite ($PtAs_2$) was identified in samples from an unusually high-iron chromite pod in dunite and clinopyroxenite from Misheguk Mountain. Also, chromite-bearing dunite, chromitite, clinopyroxenite, and sulfide-bearing gabbro in the Avan Hills, at Misheguk Mountain, and at Siniktanneyak Mountain were all found to locally contain sub-ore-grade, but anomalous concentrations of the precious metals. Abundant chromite and trace to minor amounts of gold and PGM were detected in pan concentrate samples.

None of the areas described in this report are currently accessible by road, but transportation in northwestern Alaska may improve with the development of other mineral resources in the region. The Avan Hills, which contain most of the chromite deposits described in this report, are about 20 miles east of the Red Dog Mine, which was recently connected to the northwestern Alaska coast by an all-season road.

REFERENCES

1. Arctic Environmental Information and Data Center (AEIDC), University of Alaska (Fairbanks, AK). Mineral Terranes of Alaska, 1979, 6 plates, scale 1:1,000,000.

2 . ______. Mineral Terranes of Alaska, 1982, 6 plates, scale 1:1,000,000.

3. Barnes, D.F. Bouguer Gravity Map of Northern Alaska (prepared in cooperation with the State of Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys). U.S. Geological Survey, Map 6P 913, 1977, 1 sheet, scale 1:2,500,000.

4. _____. Bouguer Gravity Map of Northern Alaska. U.S. Geological Survey Open-File Report 77-166A, 1977, 1 sheet, scale 1:1,000,000

5. Barnes, D.F., and I.L. Tailleur. Preliminary Interpretation of Geophysical Data from the Lower Noatak River Basin, Alaska. Paper in Reports and Maps of the Geological Survey released only in the Open Files (U.S. Geological Survey Circular 638, 1971). U.S. Geological Survey Open-File Report 70-18 1970, 15 pp.

6. Curtis, S.M., I. Ellersieck, C.F. Mayfield, and I.L. Tailleur. Reconnaissance Geologic Map of the De Long Mountains A1, B1, and part of C1 Quadrangles, Alaska. U.S. Geological Survey Open-File Report 83-185, 1983, 54 pp., 2 sheets, scale 1:63,360. Superseded by U.S. Geological Survey Miscellaneous Investigations Map I-1930, 1990, 2 sheets, scale 1:63,360.

7. _______. Reconnaissance Geologic Map of Southwestern Misheguk Mountain Quadrangle, Alaska. U.S. Geological Survey Open-File Report 82-611, 1982, 43 pp., 2 sheets, scale 1:63,360. Superseded by U.S. Geological Survey Miscellaneous Investigations Map I-1502, 1984, 2 sheets, scale 1:63,360.

8. Degenhart, C.E., R.J. Griffins, J.F. McOuat, and C.G. Bigelow. Mineral studies of the Western Brooks Range performed under contract to the U.S. Bureau of Mines, Contract #J0155089 (WGM Inc.).

9. Ellersieck, I., S.M. Curtis, C.F. Mayfield, and I.L. Tailleur. Reconnaissance Geologic Map of South-Central Misheguk Mountain Quadrangle, Alaska. U.S. Geological Survey Open-File Report 82-612, 1982, 38 pp., 2 sheets, scale 1:63,360. Superseded by U.S. Geological Survey Miscellaneous Investigations Map I-1504, 2 sheets, scale 1:63,360.

10. Foley, J.Y., J.C. Barker, and L.L. Brown. Critical and Strategic Minerals Investigations in Alaska: Chromium: U.S. Bureau of Mines Open-File Report 97-85, 1985, 53 pp.

11._______. Chromite Resources in Alaska: Chapter in Chromium-Chromite: Bureau of Mines Assessment and Research: U.S. Bureau of Mines Information Circular 9087, 1986, pp. 23-29.

12. Frank, C.O., and J. Zimmerman. Petrography of Nonultramafic Rocks from the Avan Hills Complex, De Long Mountains, Alaska. The U.S. Geological Survey In Alaska: Accomplishments during 1980, ed. by W. L. Coonrad. U.S. Geological Survey Circular 844, 1982, pp. 22-27.

13. Harris, R.A. Structure and Composition of Sub-Ophiolite Metamorphic Rocks, Western Brooks Range Ophiolite, Alaska: Abs. in Geological Society of America, Cordilleran Section, Abstracts with Programs, 1987, v. 19, no. 6, p. 387.

14._______. Origin, Emplacement, and Attenuation of the Misheguk Mountain Allochthon, Western Brooks Range, Alaska: Abs in Geological Society of America, Annual Meeting, Abstracts with Programs, 1988, v. 20, no. 7, p. A112.

15._______. The Brooks Range Ophiolite and its Analogues: Unpublished Ph.D. Dissertation, University College London, 1989, 520 pp.

16. Jansons, U., and D.W. Baggs. Mineral Investigations of the Misheguk Mountain and Howard Pass Quadrangles, National Petroleum Reserve-Alaska. U.S. Bureau of Mines, Open-File Report 38-80, 1980, 76 pp.

17. Mowatt, T.C. and Uldis Jansons. Platinum and Palladium in Some Mafic/Ultramafic Rocks from the Rabbit Creek Area in the Noatak Quadrangle, Alaska: U.S. Bureau of Mines Open-File Report 45-85, 1985, 23 pp.

18. Mowatt, T.C. Platinum and Palladium in Mafic-Ultramafic Igneous Rocks, Northwestern Alaska: Geochemical-Petrological Relationships, Geological and Mineral Resource Implications. Paper presented at the International Geological Congress, Washington, D.C., July 9-19, 1989.

19.______. Platinum and Palladium in Mafic-Ultramafic Rocks, Northwestern Alaska. U.S. Bureau of Land Management Open-File Report 37, 1991, 21 pp.

20. Mayfield, C.F., I. L. Tailleur, and I. Ellersieck. Stratigraphy, Structure, and Palinspastic Synthesis of the Western Brooks Range, Northwestern Alaska. U.S. Geological Survey Open-File Report 83-779, 1983, 61 pp., 5 plates.

21. Mull, C.G. Tectonic Evolution and Structural Style of the Brooks Range, Alaska: An Illustrated summary. Paper in Geologic Studies of the Cordilleran Thrust Belt, ed. by R. B. Powers Rocky Mountain Association of Geologists, v. 1, 1982, pp. 1-45.

22. Nelson, S.W., and W.H. Nelson. Geology of the Siniktanneyak Mountain Ophiolite, Howard Pass Quadrangle, Alaska. U.S. Geological Survey Miscellaneous Field Studies Map MF-1441, 1982, 1 sheet, scale 1:63,360.

23. Nelson, S.W., W.J. Nokleberg, M. Miller-Hoare, and M.W. Mullen. Siniktanneyak Mountain Ophiolite. Paper in the U.S. Geological Survey in Alaska: Accomplishments During 1978, ed. by K. M. Johnson and J.R. Williams. U.S. Geological Survey Circular 804-B, 1980, pp. B14-B16.

24. Papp, J.F. Chromium. U.S. Bureau of Mines Mineral Commodity Profile, 1983, 21 pp.

25.______. Chromium, 1989. Chapter in U.S. Bureau of Mines Mineral Yearbook, 1990, 26 pp.

26. Patton, W.W., Jr., I.L. Tailleur, W.P. Brosge', and M.A. Lanphere. Preliminary Report on the Ophiolites of Northern and Western Alaska (Pres. at Sudbury Ultramafic Conference, North American Meeting of International Working Group on Ophiolites of Continents and Comparable Oceanic Rocks, Sudbury, Ontario, 1979) Available from U.S. Geological Survey, Menlo Park, CA; Also in OR Department of Geology and Mineral Industries (Portland, OR) Bull. 95, 1977, pp. 51-57.

27. Roeder, D., and C.G. Mull. Tectonics of Brooks Range Ophiolites, Alaska. American Association of Petroleum Geologists Bull., V. 62, No. 9, Sept. 1978, pp. 1696-1701.

28. Saunders, R.H. Report on the Examination of the Sours Chromium Prospect, Noatak Quadrangle. Territory of Alaska, Department of Mines, Prospect Examination 26-1, 1955, 3 pp.

29. U.S. Bureau of Mines, Staff, Alaska Field Operations Center. A Mineral Appraisal of the Areas Traversed by the Salmon and Noatak Rivers in the Western Brooks Range: A summary report. U.S. Bureau of Mines Open-File Report 50-79, 1979, 16 pp.

30. U.S. Bureau of Mines. Mineral Commodity Summaries, 1991. U.S. Bureau of Mines, 1991, 196 pp.

31. Zimmerman, J., C.O. Frank, Sean Bryn. Mafic Rocks in the Avan Hills Ultramafic Complex, De Long Mountains. Paper in the U.S. Geological Survey in Alaska: Accomplishments During 1979, ed. by N.R. Albert and T. Hudson. U.S. Geological Survey Circular 804-B, 1980, pp. B8-B11.

32. Zimmerman, J., and P.G. Soustek. The Avan Hills Ultramafic Complex, De Long Mountains, Alaska. Paper in the U.S. Geological Survey in Alaska: Accomplishments During 1978, ed. by K.M. Johnson and

J.R. Williams. U.S. Geological Survey Circular 804-B, 1980, pp. B8-B11.

APPENDIX A. - SAMPLE KEY

Sample[1,2]	Field Number[2]	Sample[1,2]	Field Number[2]	Sample[1,2]	Field Number[2]	Sample[1,2]	Field Number[2]
IYIKROK MOUNTAIN		AVAN HILLS--CON.		AVAN HILLS--CON.		MISHEGUK MOUNTAIN--CON.	
I1P	WB20594	A14R	WB20825	A35R-B	WB16540B	M7P	WB20524
I2R	WB20593B	A15R	WB20434	A36R-A	WB16539A	M8P	WB20526
I2RM	WB20593A	A16R	WB20550	A36R-B	WB16539B	M9P	WB20528
I3R	WB20541	A17R	WB20549	A37P-A	WB16608	M10R	WB20750A
I4R	WB20562	A18R-A	WB16537A	A37P-B	WB16610	M10RM	WB20750B
I5R	WB20563B	A18R-B	WB16537B	A38R	WB18803	M11R-A	WB20555
I5RM	WB20563A	A19R	WB17594	A39R	WB18805	M11R-B	WB20556
I6R	WB20592B	A20R-A	WB20438A	A40R	WB18804	M12P	WB20570
I6RM	WB20592A	A20R-B	WB20438B	A41R-A	WB20436A	M13P	WB20566
I7P	WB20992	A21R-A	WB16601A	A41R-B	WB20436B	M14R	WB20530
I8R	WB20564	A21R-B	WB16601B	A42R-A	WB20437A	M15R	WB20502
I9P	WB20542	A22R-A	WB16538A	A42R-A	WB20437B	M16P	WB20558
I10P	WB20543	A22R-B	WB16538B	A43R	WB17646	M17R	WB20519
AVAN HILLS		A23R	WB20548	A44R	WB17645	M18P	WB20514
A1P	WB20589	A24R	WB20513A	A45P	WB16606	M19P	WB20531
A2P	WB20590	A24RM	WB20513B	A46P	WB16604	M20P	WB20568
A3R-A	WB20511A	A25R	WB20546	A47R	WB17648	M21R	WB20523
A3R-B	WB20511B	A26R	WB20547	A48R	WB16761	M22P	WB20522
A4P	WB20591	A27R	WB20583	A49R	WB16763	M23P	WB20552
A5R	WB20512C	A28R	WB20584	A50R	WB16764	M24R-A	WB20508
A5RM-A	WB20512A	A29R-A	WB20585A	A51R-A	WB16766	M24R-B	WB20534
A5RM-B	WB20512B	A29R-B	WB20585B	A51R-B	WB16767	M25	WB20509
A6R	WB20561	A30R-A	WB20586A	A52P	WB16598	M26RM	WB20510
A7R	WB20560	A30R-B	WB20586B	A53P	WB20832	M27R	WB20535
A8R-A	WB20537	A30RM-A	WB20586C	MISHEGUK MOUNTAIN		M28R-A	WB20553
A8R-B	WB20538	A30RM-B	WB20586D	M1P	WB20515	M28R-B	WB20554
A9R	WB20536	A31R-A	WB20435A	M2R-A	WB20517A	M28R-C	WB20504
A10R	WB20540	A31R-B	WB20435B	M2R-B	WB20517B	M29R	WB20503
A11R-A	WB20827A	A32P	WB20830	M3R-A	WB20516A	M30R	WB20533

Sample[1,2]	Field Number[2]	Sample[1,2]	Field Number[2]	Sample[1,2]	Field Number[2]	Sample[1,2]	Field Number[2]
A11R-B	WB20827B	A33R-A	WB16541A	M3R-B	WB20516B	SINIKTANNEYAK MOUNTAIN	
A12R-A	WB20826A	A33R-A	WB16541B	M4P	WB20557	S1P	WB18742
A12R-B	WB20826B	A34P	WB20828	M5R	WB20501		
A13R	WB20539	A35R-A	WB16540A	M6R	WB20749		

[1]Prefix key: I--Iyikrok Mountain, A--Avan Hills, M--Misheguk Mountain, S--Siniktanneyak Mountain.
[2]Suffix key: P--panned concentrate, R--rock sample, M--metallurgical rock sample. A, B, C, and D distinguish samples from same location.

APPENDIX B. - Dimensions, grade, tonnage estimates, and descriptions of chromite deposits in the western Brooks Range

TABLE B-1. - Iyikrok Mountain

Deposit	Dimensions (ft)		Grade (pct chromite)		Tonnage (st)[1]		Contained Cr_2O_3 (st)[2]	
	minimum (min)	maximum (max)	min	max	min	max	min	max
1	80 x 350 x 88		3		254,000		4,600	
		80 x 350 x 175		4		505,200		12,100
2	300 x 1,000 x 250		3		7,732,000		139,000	
		300 x 1,000 x 500		4		15,464,000		371,000

Descriptions	
1	East-striking bands of disseminated, coalescent, and massive chromite as much as 4 in. thick.
2	East- to northeast-striking bands of disseminated, coalescent, and massive chromite as much as 8 in. thick.

[1] Tonnage is quotient of volume (ft^3) divided by 9.7 ft^3/st.
[2] Contained Cr_2O_3 (st) is the product of tonnage (st) x grade (pct) x 0.6 (assumed average chromium content of chromite mineral in weight percent).

TABLE B-2. - Avan Hills

Deposit	Dimensions (ft)		Grade (pct chromite)		Tonnage (st)[1]		Contained Cr_2O_3 (st)[2]		Descriptions
	minimum	maximum	minimum	maximum	minimum	maximum	minimum	maximum	
1	5 x 40 x 10		6		206		7.4		Nodular chromite concentrated in bands that strike N 40° E. Chromite-bearing dunite is bounded on one side by 5-ft-wide peridotite layer.
		5 x 40 x 20		6		412		14.8	
2	23 x 55 x 14		10		1,800		108		Nodular chromite pod in dunite.
		23 x 55 x 28		10		3,700		220	
3	3 x 30 x 8		5		74		2.2		Elongated chromite segregations, thin chromite bands, coarse-grained disseminated chromite, and wispy chromite schlieren in dunite.
		3 x 30 x 16		8		148		7.1	
4	125 x 200 x 50		3		128,900		2,300		Chromite schlieren and bands of disseminated and coalescent chromite in stringer zone in dunite.
		125 x 200 x 100		4		257,700		6,200	
5	75 x 90 x 23		3		16,000		290		Disseminated chromite bands as much as 1 in. thick.
		75 x 90 x 45		3		31,300		560	
6	2 x 20 x 5		3		21		0.4		Discontinuous bands of coalescent chromite in dunite.
		2 x 20 x 10		5		42		1.3	
7	150 x 1,060 x 265		5		4,344,000		130,300		Northeast-striking, steeply dipping bands of disseminated, coalescent, and massive chromite in dunite outcrop, rubble, and regolith.
		1,325 x 150 x 663		10		13,600,000		816,000	
8	20 x 200 x 50		3		20,600		370		Small pods, schlieren, and thin bands of disseminated, coalescent, and massive chromite in dunite.
		20 x 200 x 100		3		41,200		740	

Deposit	Dimensions (ft)		Grade (pct chromite)		Tonnage (st)[1]		Contained Cr_2O_3 (st)[2]		Descriptions
	minimum	maximum	minimum	maximum	minimum	maximum	minimum	maximum	
9	4 x 30 x 8		25		99		14.8		Bands of coalescent and massive chromite in dunite. Covered on both ends.
		4 x 45 x 23		40		427		102	
10	90 x 150 x 38		3		52,900		950		Discontinuous, less than 1 in. thick, bands of disseminated and coalescent chromite in serpentinized peridotite.
		90 x 150 x 75		5		104,400		3,100	
11	50 x 80 x 20		5		8,200		240		Disseminated and coalescent coarse-grained chromite and thin chromite bands in dunite.
		50 x 80 x 40		5		16,500		500	
12	25 x 110 x 28		8		7,900		380		Discontinuous, irregular, elongated, massive chromite segregations.
		25 x 110 x 55		8		15,600		750	
13	10 x 50 x 13		10		670		40		Banded chromite with bands up to 4 in. thick.
		10 x 50 x 25		10		1,300		78	
14	3 x 100 x 25		20		773		93		Banded chromite with bands up to 2.5 in. thick.
		3 x 100 x 50		20		1,500		180	
15	50 x 500 x 125		5		322,000		9,700		Numerous pods and irregular segregations of massive chromite sporadically distributed throughout area.
		75 x 750 x 325		5		1,885,000		56,600	
16	100 x 300 x 75		5		232,000		7,000		Chromite bands in dunite outcrop and rubblecrop.
		100 x 300 x 150		10		464,000		27,800	
17	175 x 300 x 75		5		406,000		12,000		Stringer zone comprising multiple 10- to 15-ft-wide banded zones. Individual chromite bands average 1 to 2 in. thick.
		175 x 300 x 150		5		812,000		24,400	

Deposit	Dimensions (ft)		Grade (pct chromite)		Tonnage (st)[1]		Contained Cr_2O_3 (st)[2]		Descriptions
	minimum	maximum	minimum	maximum	minimum	maximum	minimum	maximum	
18	10 x 70 x 18		10		1,300		78		Numerous parallel chromite bands in dunite and peridotite. Massive bands up to 2 in. thick.
		10 x 70 x 35		15		2,500		230	
19	150 x 1,500 x 375		5		8,698,000		261,000		Abundant chromite bands in outcrop at ridge and in rubblecrop and talus downslope for more than 1,500 ft.
		150 x 1,500 x 750		5		17,397,000		522,000	
20	100 x 300 x 75		7		232,000		9,700		Stringer zone containing numerous chromite bands as much as 10 in. thick.
		100 x 300 x 150		7		464,000		19,500	
21	50 x 150 x 38		5		29,400		880		Numerous pods of massive chromite in elongate zone in dunite outcrop and rubblecrop.
		50 x 150 x 75		5		58,000		1,700	
22	50 x 50 x 13		5		3,400		102		Irregular massive chromite bands in dunite outcrop and rubble.
		50 x 50 x 25		10		6,400		380	
23	6 x 30 x 8		3		148		2.7		Small stringer zone in dunite with chromite bands as much as 4 in. thick.
		6 x 30 x 15		5		278		8.4	
24	10 x 300 x 75		3		23,200		418		Narrow stringer zone with bands of disseminated chromite.
		10 x 300 x 150		5		46,400		1,400	
25	50 x 350 x 88		10		158,800		9,500		Massive chromite schlieren in layered dunite, clinopyroxenite, wehrlite.
		75 x 438 x 219		15		742,000		66,800	
26	7 x 82 x 21		8		12,00		58		Massive chromite schlieren bounded by dunite and wehrlite.
		7 x 123 x 62		10		5,500		330	

[1] Tonnage is the quotient of volume (ft^3) divided by 9.7 ft^3/st.
[2] Contained Cr_2O_3 (st) is the product of tonnage (st) x grade (pct) x 0.6 (assumed average chromium content of chromite mineral in weight percent).

TABLE B-3. - Misheguk Mountain

Deposit	Dimensions (ft)		Grade (pct chromite)		Tonnage (st)[1]		Contained Cr_2O_3 (st)[2]		Descriptions
	minimum	maximum	minimum	maximum	minimum	maximum	minimum	maximum	
1	100 x 350 x 88		6		317,500		11,400		Massive and coalescent chromite schlieren and discontinuous bands in dunite outcrop and rubblecrop.
		100 x 350 x 175		6		631,400		22,700	
2	300 x 750 x 188		3		4,360,800		78,500		Chromite bands in dunite cirque wall and abundant chromite bands in dunite talus and rubble at base of cirque.
		300 x 750 x 375		5		8,698,500		261,000	
3	100 x 400 x 100		3		412,400		7,400		Numerous banded intervals as much as 10 in. thick with individual chromite bands as much as 3 in. thick.
		100 x 400 x 200		4		824,700		19,800	
4	80 x 200 x 50		3		82,500		1,500		Stringer zone with numerous discontinuous chromite bands in dunite and peridotite.
		80 x 200 x 100		4		165,000		4,000	
5	80 x 360 x 90		3		267,200		4,800		Disseminated and coalescent in dunite rubblecrop.
		80 x 360 x 180		5		534,400		16,000	
6	100 x 600 x 150		3		927,800		16,700		Coarse-grained disseminated chromite and massive chromite clots in dunite.
		100 x 600 x 300		3		1,855,700		33,400	
7	25 x 110 x 28		3		7,900		142		Coalescent and massive chromite schlieren and bands in dunite.
		25 x 110 x 55		4		15,600		374	

Deposit	Dimensions (ft)		Grade (pct chromite)		Tonnage (st)[1]		Contained Cr_2O_3 (st)[2]		Descriptions
	minimum	maximum	minimum	maximum	minimum	maximum	minimum	maximum	
8	50 x 200 x 50		3		51,500		930		Stringer zone with disseminated chromite and coalescent and massive chromite bands.
		50 x 200 x 100		5		103,100		3,100	
9	15 x 100 x 25		3		3,900		70		Stringer zone with discontinuous chromite bands.
		15 x 100 x 50		5		7,700		231	

[1] Tonnage is the quotient of volume (ft^3) divided by 9.7 ft^3/st.
[2] Contained Cr_2O_3 (st) is the product of tonnage (st) x grade (pct) x 0.6 (assumed average chromium content of chromite mineral in weight percent).

APPENDIX C. - Analytical results for gravity table concentrates from samples from Iyikrok Mountain, Avan Hills, and Misheguk Mountain

Product	wt pct	Analytical results (pct)					Cr distribution (pct)	Cr-Fe ratio
		Cr_2O_3	Fe	MgO	Al_2O_3	SiO_2		
SAMPLE I2RM, IYIKROK MOUNTAIN								
28- by 65-mesh concentrate[1]	9.5	59.6	12.7	15.4	7.4	1.6	13.1	3.2
Minus 65-mesh: Rougher concentrate[1]	45.0	60.2	12.2	15.5	7.2	2.0	62.7	3.4
Rougher middlings and coarse tailings	35.2	20.8	NAv	NAv	NAv	NAv	17.0	NAv
Scavenger concentrate	9.0	54.5	11.7	18.9	6.5	5.3	11.4	3.2
Scavenger tailings	26.2	9.2	NAv	NAv	NAv	NAv	5.6	NAv
Rougher slime tailings	10.3	30.2	NAv	NAv	NAv	NAv	7.2	NAv
Composite or total	100.0	43.2	NAp	NAp	NAp	NAp	100.0	NAp
Calculated composite concentrate[2]	63.5	59.3	12.2	16.0	7.1	2.4	87.2	3.3

Product	wt pct	Analytical results (pct)					Cr distribution (pct)	Cr-Fe ratio
		Cr_2O_3	Fe	MgO	Al_2O_3	SiO_2		
SAMPLE I5RM, IYIKROK MOUNTAIN								
28- by 65-mesh concentrate[3]	8.5	60.2	13.3	14.5	7.4	1.9	12.3	3.1
Minus 65-mesh: Rougher concentrate[4]	50.9	59.9	12.9	14.4	7.3	1.8	73.1	3.2
Rougher middlings and coarse tailings	31.0	20.8	NAv	NAv	NAv	NAv	7.7	NAv
Scavenger concentrate	7.2	55.5	12.1	16.8	6.6	4.9	1.8	3.1
Scavenger tailings	23.8	10.3	NAv	NAv	NAv	NAv	5.9	NAv
Rougher slime tailings	9.6	30.2	NAv	NAv	NAv	NAv	6.9	NAv
Composite or total	100.0	43.2	NAp	NAp	NAp	NAp	100.0	NAp
Calculated composite concentrate[2]	66.6	59.5	12.9	14.7	7.3	2.2	87.2	3.2

Product	wt pct	Analytical results (pct)					Cr distribution (pct)	Cr-Fe ratio
		Cr_2O_3	Fe	MgO	Al_2O_3	SiO_2		
SAMPLE I6RM, IYIKROK MOUNTAIN								
28- by 65-mesh concentrate[4]	13.8	56.8	13.7	14.3	9.4	1.7	16.6	2.8
Minus 65-mesh: Rougher concentrate[4]	46.5	57.1	13.9	14.5	8.7	2.2	56.3	2.8
Rougher middlings and coarse tailings	28.7	30.8	NAv	NAv	NAv	NAv	18.7	NAv
Scavenger concentrate	11.3	53.4	13.5	16.2	9.3	3.9	12.8	2.7
Scavenger tailings	17.4	16.1	NAv	NAv	NAv	NAv	5.9	NAv
Rougher slime tailings	11.0	35.9	NAv	NAv	NAv	NAv	8.4	NAv
Composite or total	100.0	47.2	NAp	NAp	NAp	NAp	100.0	NAp
Calculated composite concentrate[2]	71.6	56.5	13.8	14.7	8.9	2.4	85.7	2.8

Product	wt pct	Analytical results (pct)					Cr distribution (pct)	Cr-Fe ratio
		Cr_2O_3	Fe	MgO	Al_2O_3	SiO_2		
SAMPLE A5RM-A, AVAN HILLS								
28- by 65-mesh concentrate[4]	23.9	51.0	12.0	16.2	12.0	4.2	26.0	2.9
Minus 65-mesh: Rougher concentrate[4]	49.0	54.7	11.6	14.0	12.6	1.9	57.1	3.2
Rougher middlings and coarse tailings	21.3	27.3	NAv	NAv	NAv	NAv	12.4	NAv
Scavenger concentrate	10.3	46.9	11.7	17.2	11.0	7.2	10.3	2.7
Scavenger tailings	11.0	9.0	NAv	NAv	NAv	NAv	2.1	NAv
Rougher slime tailings	5.8	36.1	NAv	NAv	NAv	NAv	4.5	NAv
Composite or total	100.0	46.9	NAp	NAp	NAp	NAp	100.0	NAp
Calculated composite concentrate[2]	83.2	52.7	11.7	15.0	12.4	2.0	93.4	3.1

Product	wt pct	Analytical results (pct)					Cr distribution (pct)	Cr-Fe ratio
		Cr_2O_3	Fe	MgO	Al_2O_3	SiO_2		
SAMPLE A5RM-B, AVAN HILLS								
28- by 65-mesh concentrate[5]	10.6	46.8	12.3	16.3	11.7	6.2	20.5	2.6
Minus 65-mesh: Rougher concentrate[6]	21.0	52.2	12.3	14.0	12.8	2.9	45.2	2.9
Rougher middlings and coarse tailings	18.9	25.3	NAv	NAv	NAv	NAv	19.7	NAv
Scavenger concentrate	7.4	43.0	11.2	18.6	10.7	9.3	13.1	2.6
Scavenger tailings	11.5	13.9	NAv	NAv	NAv	NAv	6.6	NAv
Rougher slime tailings	30.8	3.6	NAv	NAv	NAv	NAv	4.6	NAv
Rougher slime tailings	18.7	13.0	NAv	NAv	NAv	NAv	10.0	NAv
Composite or total	100.0	43.2	NAp	NAp	NAp	NAp	100.0	NAp
Calculated composite concentrate[2]	39.0	49.0	12.1	15.5	12.1	5.0	78.8	2.8

Product	wt pct	Analytical results (pct)					Cr distribution (pct)	Cr-Fe ratio
		Cr_2O_3	Fe	MgO	Al_2O_3	SiO_2		
SAMPLE A24RM, AVAN HILLS								
28- by 65-mesh concentrate[4]	59.9	55.5	13.7	12.5	10.9	0.6	61.9	2.8
Minus 65-mesh: Rougher concentrate[4]	30.4	56.0	13.2	12.5	11.2	1.1	31.8	2.9
Rougher middlings and coarse tailings	6.3	43.4	NAv	NAv	NAv	NAv	5.1	NAv
Scavenger concentrate	4.9	53.2	12.9	14.3	10.5	2.5	4.9	2.8
Scavenger tailings	1.4	8.9	NAv	NAv	NAv	NAv	.2	NAv
Rougher slime tailings	3.4	19.4	NAv	NAv	NAv	NAv	1.2	NAv
Composite or total	100.0	53.7	NAp	NAp	NAp	NAp	100.0	NAp
Calculated composite concentrate[2]	95.2	55.5	13.5	12.6	11.0	.9	98.6	2.8

Product	wt pct	Analytical results (pct)					Cr distribution (pct)	Cr-Fe ratio
		Cr_2O_3	Fe	MgO	Al_2O_3	SiO_2		
SAMPLE A30RM-A, AVAN HILLS								
28- by 65-mesh concentrate[7]	3.2	52.3	15.4	13.4	11.7	1.2	13.6	2.3
Minus 65-mesh: Rougher concentrate[4]	14.6	51.0	15.0	14.2	12.9	1.5	60.5	2.3
Rougher middlings	24.7	7.4	NAv	NAv	NAv	NAv	15.0	NAv
Rougher coarse tailings	41.8	1.3	NAv	NAv	NAv	NAv	5.5	NAv
Scavenger concentrate	3.1	37.0	12.5	24.1	9.0	12.7	9.3	2.0
Scavenger tailings	21.6	3.2	NAv	NAv	NAv	NAv	5.7	NAv
Rougher slime tailings	15.7	4.3	NAv	NAv	NAv	NAv	5.4	NAv
Composite or total	100.0	12.3	NAp	NAp	NAp	NAp	100.0	NAp
Calculated composite concentrate[2]	20.9	49.1	14.7	15.6	12.1	3.8	83.4	2.3

Product	wt pct	Analytical results (pct)					Cr distribution (pct)	Cr-Fe ratio
		Cr_2O_3	Fe	MgO	Al_2O_3	SiO_2		
SAMPLE A30RM-B, AVAN HILLS								
28- by 65-mesh concentrate[4]	14.5	53.6	15.2	15.1	11.2	2.8	18.7	2.4
Minus 65-mesh: Rougher concentrate[4]	46.3	54.9	15.0	14.0	11.0	1.6	61.2	2.5
Rougher middlings and coarse tailings	29.6	19.9	NAv	NAv	NAv	NAv	14.2	NAv
Scavenger concentrate	8.0	44.1	12.8	21.2	9.1	9.1	8.5	2.4
Scavenger tailings	21.6	11.0	NAv	NAv	NAv	NAv	5.7	NAv
Rougher slime tailings	9.6	25.7	NAv	NAv	NAv	NAv	5.9	NAv
Composite or total	100.0	41.6	NAp	NAp	NAp	NAp	100.0	NAp
Calculated composite concentrate[2]	68.8	53.4	14.8	15.1	10.8	2.7	88.3	2.5

Product	wt pct	Analytical results (pct)					Cr distribution (pct)	Cr-Fe ratio
		Cr_2O_3	Fe	MgO	Al_2O_3	SiO_2		
SAMPLE M10RM, MISHEGUK MOUNTAIN								
28- by 65-mesh concentrate[8]	3.3	48.9	13.1	15.6	15.1	2.7	8.0	2.6
Minus 65-mesh: Rougher concentrate[4]	22.5	49.8	12.8	14.9	14.9	2.3	55.5	2.7
Rougher middlings and coarse tailings	34.8	14.8	NAv	NAv	NAv	NAv	25.6	NAv
Scavenger concentrate	4.2	43.6	11.6	19.3	13.6	7.3	9.0	2.6
Scavenger tailings	30.6	10.9	NAv	NAv	NAv	NAv	16.5	NAv
Rougher coarse tailings	22.8	3.5	NAv	NAv	NAv	NAv	4.0	NAv
Rougher slime tailings	16.6	8.5	NAv	NAv	NAv	NAv	7.0	NAv
Composite or total	100.0	20.2	NAp	NAp	NAp	NAp	100.0	NAp
Calculated composite concentrate[2]	30.0	49.9	12.7	15.6	14.7	3.0	72.5	2.6

Product	wt pct	Analytical results (pct)					Cr distribution (pct)	Cr-Fe ratio
		Cr_2O_3	Fe	MgO	Al_2O_3	SiO_2		
SAMPLE M26RM, MISHEGUK MOUNTAIN								
28- by 65-mesh concentrate[9]	38.2	50.9	11.5	16.5	14.5	2.2	41.0	3.0
Minus 65-mesh: Rougher concentrate[4]	40.5	51.7	11.4	15.8	14.3	1.8	44.2	3.1
Rougher middlings and coarse tailings	14.6	34.6	NAv	NAv	NAv	NAv	10.6	NAv
Scavenger concentrate	9.8	48.8	11.1	16.9	13.6	4.0	10.1	3.0
Scavenger tailings	4.8	5.6	NAv	NAv	NAv	NAv	.5	NAv
Rougher slime tailings	6.7	29.4	NAv	NAv	NAv	NAv	4.2	NAv
Composite or total	100.0	47.4	NAp	NAp	NAp	NAp	100.0	NAp
Calculated composite concentrate[2]	88.5	51.0	11.4	16.1	14.2	2.5	95.3	3.1

NAp Not applicaple. NAv Not available.
[1]Precious metals analysis, oz/st: Pt, <0.001; Pd, <0.001; Au, <0.0008; Ag, <0.04.
[2]Includes 28- by 65-mesh concentrate, rougher concentrate, and scavenger concentrate values.
Precious metals analyitical results in oz/st:
[3]Pt, <0.001; Pd, <0.001; Au, 0.003; Ag, <0.04.
[4]Pt, <0.001; Pd, <0.001; Au, <0.0008; Ag, <0.04.
[5]Pt, <0.001; Pd, 0.016; Au, <0.0008; Ag, <0.04.
[6]Pt, <0.001; Pd, <0.001; Au, 0.024; Ag, <0.04
[7]Pt, <0.001; Pd, <0.001; Au, 0.007; Ag, <0.04.
[8]Pt, <0.001; Pd, <0.001; Au, 0.028; Ag, <0.04.
[9]Pt, <0.001; Pd, <0.001; Au, <0.0008; Ag, 0.07