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Chromite Deposits Along the Border Ranges Fault, Southern Alaska

(In Two Parts)

2. Mineralogy and Results of Beneficiation Tests

By D. C. Dahlin, D. E. Kirby, and L. L. Brown

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	min	minute
in	inch	oz	ounce
lb	pound	pct	percent
μm	micrometer	wt pct	weight percent

CHROMITE DEPOSITS ALONG THE BORDER RANGES FAULT, SOUTHERN ALASKA

(In Two Parts)

2. Mineralogy and Results of Beneficiation Tests

By D. C. Dahlin,[1] D. E. Kirby,[1] and L. L. Brown[2]

ABSTRACT

To identify and characterize potential domestic chromium resources, the Bureau of Mines investigated podiform chromite deposits along the Border Ranges Fault in southern Alaska. Part 1 of this two-part report describes an extensive field investigation and preliminary resource evaluation studies by the Bureau's Alaska Field Operations Center. This paper, part 2, describes the mineralogy of 38 samples that were collected from low-grade deposits in the Chugach Mountains, on the Kenai Peninsula, and on Kodiak Island, and presents the results of laboratory batch beneficiation tests designed to concentrate the chromite.

The samples are peridotites and chromitites that consist primarily of variable amounts of chromite, olivine, and serpentine. They were beneficiated by a sequence of grinding, sizing, and gravity concentration operations. Twenty-four high-chromium or marginal high-chromium chromite concentrates, six high-iron or marginal high-iron chromite concentrates, and five submarginal concentrates were produced with chromium recoveries that ranged from 37 to 95 pct. Three very low-grade samples were not beneficiated. These results indicate that several of the deposits may be significant chromium resources.

Potential precious metals association with the chromite was also investigated. Analysis of these samples indicates that the chromite deposits are not good platinum sources.

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INTRODUCTION

The United States is dependent on foreign sources for chromium, a commodity that is essential to the Nation's metallurgical, chemical, and refractory industries. Metallurgical applications of chromium include stainless steels and many other ferrous and nonferrous alloys. Chemical applications include plating, pigment production, and leather tanning. Chromite refractories are used in high-temperature applications such as furnace and kiln linings and as a foundry molding material. Many studies have been done to reduce the chromium demand of these industries by substitution; although some satisfactory substitutes have been developed, substitutes have not been found for the bulk of chromium uses.

The United States has no domestic production or economic reserves of chromite, the only commercial ore of chromium, and must rely on imports or stockpiles to meet national needs. Although world reserves of chromite are adequate to meet forecasted world demand, sensitive political and economic situations and geography could jeopardize our supply of chromite.[3] The larger, high-grade chromite deposits are located in the Eastern Hemisphere. The majority of recent chromite imports have been from the Republic of South Africa (48 pct of the total), the Soviet Union (17 pct), and the Philippines (13 pct).[4]

The Bureau of Mines is characterizing potential domestic chromite sources and devising processing techniques to make chromium from these sources available in the event of supply disruptions. The Bureau's Alaska Field Operations Center reported on reconnaissance investigations of three ultramafic complexes in central Alaska,[5] and research was performed at the Albany (OR) Research Center, to identify the mineralogy and beneficiate chromite-bearing samples from 10 sites within the three ultramafic bodies.[6] Subsequently, similar field investigations were undertaken on low-grade chromite deposits along the Border Ranges Fault in southern Alaska.[7] Figure 1 shows the locations of the deposits. This paper, part 2 of the investigation, summarizes mineralogical and beneficiation studies on 38 samples collected within this study area.

ACKNOWLEDGMENT

The authors thank the Anaconda Minerals Co. for providing chromite samples from Red Mountain and the Windy River Valley on Kenai Peninsula under Memorandum of Agreement 14-09-0070-937 with the Bureau of Mines.

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[3]Papp, J. F. Chromium. BuMines Mineral Commodity Profile, 1983, 21 pp.

[4]Papp, J. F. Chromium. Sec. in BuMines Mineral Commodity Summaries 1984, pp. 32-33.

[5]Foley, J. Y., and M. M. McDermott. Podiform Chromite Occurrences in the Caribou Mountain and Lower Kanuti River Areas, Central Alaska. Part I: Reconnaissance Investigations. BuMines IC 8915, 1983, 27 pp.

[6]Dahlin, D. C., L. L. Brown, and J. J. Kinney. Podiform Chromite Occurrences in the Caribou Mountain and Lower Kanuti River Areas, Central Alaska. Part II: Beneficiation. BuMines IC 8916, 1983, 15 pp.

[7]Foley, J. Y., and J. C. Barker. Chromite Deposits Along the Border Ranges Fault, Southern Alaska (In Two Parts). 1. Report of Field Investigations and Descriptions of Chromite Deposits. BuMines IC 8990, 1984, 57 pp.

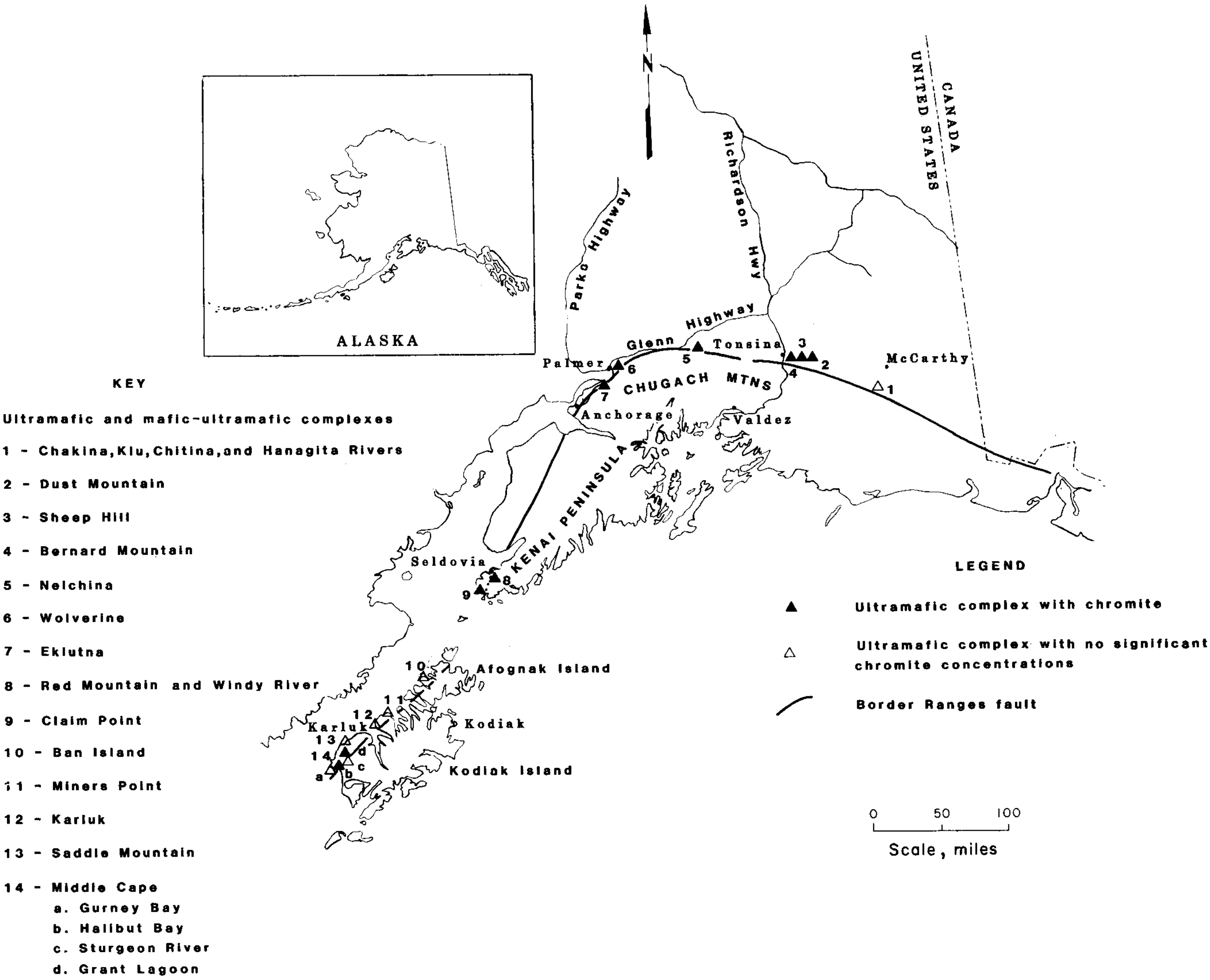

FIGURE 1. - Map of southern Alaska showing ultramafic and mafic-ultramafic complexes investigated. Base from USGS 1:500,000-scale map of Alaska.

MINERALOGY

Bulk samples for mineralogical characterization and beneficiation studies were selected from chromite-bearing areas in ultramafic and mixed mafic-ultramafic rock complexes, which are the common rock types associated with chromite. These rocks contain less than 45 pct SiO_2, are generally dark colored, and have a high specific gravity. The mineralogy of these rocks is normally uncomplicated; they are sometimes monomineralic, but they usually consist of variable amounts of olivine, ferromagnesian silicate minerals (pyroxene and amphibole), and serpentine. These ultrabasic rocks commonly host the oxide ore minerals, magnetite and chromite. They may contain minor amounts of the sulfides of iron, copper, and nickel and traces of the platinum-group metals. Ultrabasic rocks are virtually devoid of feldspar. Chlorite and mixed hydrated iron oxide minerals are usually present as alteration products. Common rock types encountered in the ultramafic portions of mafic-ultramafic complexes include the following:

Dunite--almost pure olivine.

Peridotite--a variable mixture of olivine with some pyroxene.

Pyroxenite--pyroxene, usually of one variety.

Serpentinite--a mixture of serpentine-group minerals.

To collect samples with a chromite content sufficient for metallurgical testing, each bulk sample was intentionally high-graded from surface exposures or was collected as a channel sample from high-grade portions of the deposit. Head analyses of the samples are shown in table 1. The Cr_2O_3 content ranged from 0.6 to 47.5 pct.

TABLE 1. - Head analyses of chromite samples from deposits along the Border Ranges Fault, percent

Location	Sample	Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2
Tonsina area:						
Bernard Mountain..................	BM1M	39.9	12.4	10.0	22.2	10.0
	BM2M	41.4	11.5	13.0	19.9	7.3
	BM3M	24.8	12.0	7.0	28.6	18.9
	BM4M	25.9	10.1	10.3	28.5	16.8
	BM5M	45.7	13.6	9.3	17.3	6.6
	BM6M	34.2	12.5	8.6	23.7	14.0
	BM7M	27.9	8.5	4.7	30.2	19.9
Sheep Hill........................	SH1M	.6	12.3	.8	43.4	35.3
	SH2M	22.9	11.5	4.9	29.6	19.0
	SH3M	36.1	23.3	17.7	11.4	2.0
	SH4M	27.0	13.4	7.2	26.1	18.2
Dust Mountain.....................	DM1M	17.7	25.2	17.2	18.3	10.8
	DM2M	1.5	7.9	.7	45.1	35.7
	DM3M	.8	6.3	.3	45.9	36.6
Palmer area:						
Wolverine Complex.................	WC1M	19.6	4.5	6.3	33.2	24.0
Kenai Peninsula:						
Red Mountain......................	RM1M[1]	8.3	6.2	1.5	47.9	34.4
	RM2M	29.1	9.4	5.9	29.7	19.6
	RM3M	39.6	9.7	7.0	26.2	13.4
	RM4M	21.9	7.7	4.0	37.0	25.5
	RM5M[1]	4.6	6.1	.8	50.3	36.2
	RM6M[1]	10.1	6.3	1.6	46.7	33.8
Windy River.......................	WR1S[2]	2.7	7.2	1.3	42.6	39.9
	WR2S[2]	4.5	7.6	3.1	34.6	40.7
	WR3S[2]	2.1	6.7	3.8	30.0	45.2
	WR4S[1,2]	1.8	6.9	2.7	34.0	43.9
Claim Point.......................	CP1M	21.6	7.4	3.6	38.6	26.2
	CP2M	31.0	10.1	6.0	30.2	18.4
Kodiak Island:						
Halibut Bay.......................	HB1M	22.4	14.9	5.5	31.8	20.4
	HB2M	16.7	14.5	7.1	31.9	22.3
	HB3M	47.5	11.2	8.4	19.1	7.4
	HB4M	7.7	12.1	5.0	33.1	29.6
	HB5M	.6	10.9	5.5	17.8	46.9
	HB6M	21.2	7.8	3.7	33.6	23.2
	HB7M	23.2	10.5	5.1	34.2	22.7
	HB8M	38.6	11.8	11.7	24.4	9.8
	HB9M	42.1	10.5	8.7	24.8	9.6
Grant Lagoon......................	GL1M	7.7	5.7	.6	41.3	31.2
Miners Point......................	MP1M	5.1	6.9	1.5	40.6	30.3

[1]Composite sample provided by the Anaconda Minerals Co.
[2]Placer sample.

The samples are identified by location and by sample number in the same manner as they are in part 1. Appendix B correlates the sample numbers used in this report with sample numbers assigned in the field.

Representative specimens were selected from each sample for petrographic examination and mineralogical characterization. Detailed mineralogical and liberation studies were done on samples split from sized fractions prepared for beneficiation studies and on beneficiation products.

Binocular and petrographic microscopy, magnetic separation techniques, polished surface studies, and, as needed, scanning electron microscopy and electron microprobe examinations were used to determine the mineral composition of the samples. Table 2 shows the estimated mineralogical compositions based on weight. The numbers are calculated composites from determinations made on size fractions from each sample.

High-purity chromite concentrates were prepared from gravity table concentrates by carefully controlled magnetic separation. Each sample was separated at closely spaced field settings on a laboratory model isodynamic magnetic separator, and the fraction that best represented the chromite in the sample, as determined by optical examination, was analyzed. Results are given in table 3. All are magnesian-aluminian or aluminian-magnesian chromites, depending on whether the MgO or Al_2O_3 analysis is greater. Several of the samples have nearly equal MgO and Al_2O_3 analyses. Ten are, in addition, mineralogically high-iron varieties of chromite because the Cr:Fe ratios are less than 1.9:1, the Cr:Fe ratio of theoretical chromite ($FeCr_2O_4$). Some of the high iron analyses may be attributed to intergrown and admixed magnetite.

CHROMITE SAMPLES

In the following descriptions, samples of similar mineralogy and character from an area have been grouped together.

TONSINA AREA

Bernard Mountain

BM1M, BM3M, and BM4M consist of mixtures of chromite and olivine that vary from massive, fractured chromite to almost pure olivine. Generally, the chromite occurs as fine to coarse euhedral grains abundantly to sparsely disseminated or banded in a massive and variably altered olivine matrix. Minor (less than about 5 pct) amounts of serpentine occur on slickensides and fracture surfaces, along with trace (less than about 1 pct) amounts of the pink to purple chromian chlorite, kaemmererite. Minor ferromagnesian silicate minerals and chlorite are also present, and one specimen contained some of the bright green chromian garnet, uvarovite. The olivine ranges from being relatively fresh to being completely altered to serpentine and chlorite. Weathered surfaces are variably iron stained and exhibit a buckskin color which is typical of dunite. Most of the chromite is liberated at about 65 mesh. Considerable liberation occurs at coarser sizes, but some chromite remains locked with gangue at finer sizes because of the wide variation in chromite crystal sizes in the rock.

BM2M consists of massive crystalline to euhedral crystalline, closely disseminated chromite in an altered olivine matrix. A minor amount of kaemmererite is present. Liberation of the chromite is complete at 65 mesh, and most would be liberated at about 35 mesh.

BM5M consists of highly fractured, massive chromite with randomly distributed, iron-stained serpentine. A few lenses of altered olivine are present that contain minor amounts of small euhedral chromite crystals.

TABLE 2. - Estimated mineral composition of samples from deposits along the Border Ranges Fault, percent

Location	Sample	Chromite	Olivine	Serpentine	Magnetics[1]	Chlorite	Fe-Mg silicates	Sulfides
Tonsina area:								
Bernard Mountain.	BM1M	66	29	2	1	3	ND	ND
	BM2M	80	17	ND	ND	3	Tr	ND
	BM3M	47	52	ND	1	Tr	ND	Tr
	BM4M	53	40	2	Tr	4	Tr	ND
	BM5M	75	3	21	1	Tr	Tr	ND
	BM6M	59	16	21	4	ND	Tr	Tr
	BM7M	41	2	55	Tr	Tr	2	ND
Sheep Hill.......	SH1M	Tr	90	Tr	9	ND	1	Tr
	SH2M	33	23	42	1	Tr	ND	Tr
	SH3M	94	4	Tr	1	1	Tr	ND
	SH4M	52	24	17	Tr	Tr	6	ND
Dust Mountain....	DM1M	12	24	1	60	2	2	ND
	DM2M	6	86	2	3	Tr	2	ND
	DM3M	2	2	93	1	ND	2	ND
Palmer area:								
Wolverine Complex	WC1M	36	40	20	Tr	3	ND	Tr
Kenai Peninsula:								
Red Mountain.....	RM1M[2]	18	83	Tr	ND	ND	ND	ND
	RM2M	51	39	10	Tr	ND	Tr	Tr
	RM3M	62	20	18	Tr	ND	Tr	Tr
	RM4M	37	53	10	Tr	ND	Tr	Tr
	RM5M[2]	8	71	20	1	ND	Tr	Tr
	RM6M[2]	13	79	8	Tr	ND	Tr	Tr
Windy River......	WR1S[3]	6	77	Tr	1	ND	14	ND
	WR2S[3]	3	40	34	2	ND	21	ND
	WR3S[3]	3	27	47	2	ND	22	Tr
	WR4S[2,3,4]	6	44	35	6	ND	6	ND
Claim Point......	CP1M	42	57	ND	1	ND	ND	Tr
	CP2M	59	35	5	Tr	ND	ND	Tr
Kodiak Island:								
Halibut Bay......	HB1M	30	66	ND	3	ND	ND	Tr
	HB2M	44	53	1	2	ND	ND	ND
	HB3M	69	ND	31	Tr	Tr	ND	ND
	HB4M	3	28	24	44	Tr	2	ND
	HB5M[5]	NA	NA	NA	NA	NA	NA	NA
	HB6M	42	10	47	1	Tr	ND	ND
	HB7M	40	60	ND	Tr	ND	ND	ND
	HB8M	72	27	ND	ND	ND	1	ND
	HB9M	81	19	ND	ND	ND	ND	ND
Grant Lagoon.....	GL1M	7	2	86	5	ND	ND	Tr
Miners Point.....	MP1M	3	1	90	6	ND	Tr	ND

NA Not analyzed. ND Not detected. Tr Trace.

[1] Minerals removable with a hand magnet.

[2] Composite sample provided by the Anaconda Minerals Co.

[3] Placer sample.

[4] Also contains 3 pct quartz and feldspar.

[5] Sample not analyzed for mineral composition.

NOTE.--Totals may not add to 100 pct owing to independent rounding.

TABLE 3. - High-purity concentrates of samples from deposits along the Border Ranges Fault

Location	Sample	Analysis, pct					Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2	
Tonsina area:							
Bernard Mountain..................	BM1M	55.4	12.8	13.1	15.9	0.8	3.0
	BM2M	52.0	13.5	15.2	15.5	1.0	2.6
	BM3M	49.4	17.6	13.5	12.9	1.1	1.9
	BM4M	48.5	14.6	17.6	14.7	.6	2.3
	BM5M	55.5	15.5	11.5	14.2	1.1	2.5
	BM6M	53.8	16.2	11.7	13.3	.5	2.3
	BM7M	58.5	14.1	9.2	14.5	.6	2.8
Sheep Hill.......................	SH2M	55.1	17.1	11.0	13.0	.5	2.2
	SH3M	39.2	26.4	18.4	10.7	.0	1.0
	SH4M	51.0	20.3	12.6	11.7	.9	1.7
Dust Mountain....................	DM1M	39.9	24.0	14.9	11.8	2.8	1.1
Palmer area:							
Wolverine Complex................	WC1M	47.5	20.9	11.5	12.6	2.0	1.6
Kenai Peninsula:							
Red Mountain.....................	RM1M	55.0	16.3	8.5	14.9	.9	2.3
	RM2M	55.4	14.7	10.3	13.6	.8	2.6
	RM3M	58.8	13.0	9.5	15.1	.5	3.1
	RM4M	58.9	14.8	8.8	14.3	.8	2.7
	RM5M	56.1	14.4	9.2	14.0	.9	2.7
	RM6M	56.0	15.7	8.2	14.8	.7	2.7
Windy River......................	WR1S	53.5	21.5	10.9	10.0	.5	1.7
	WR2S	53.5	20.6	10.5	10.1	.4	1.8
	WR3S	52.6	20.0	10.8	10.0	.6	1.8
	WR4S	51.9	19.7	10.3	11.1	.6	1.8
Claim Point......................	CP1M	58.2	14.6	8.1	12.4	.8	2.7
	CP2M	55.1	14.8	9.9	14.1	1.0	2.5
Kodiak Island:							
Halibut Bay......................	HB1M	50.6	16.1	10.3	15.1	1.4	2.1
	HB2M	40.0	21.0	15.4	13.4	1.7	1.3
	HB3M	55.5	13.6	9.3	16.9	3.1	2.8
	HB4M	34.6	22.1	19.7	12.7	3.7	1.1
	HB6M	53.5	14.0	8.8	15.9	2.6	2.6
	HB7M	53.5	17.3	11.7	12.8	1.1	2.1
	HB8M	51.6	13.9	14.4	15.7	1.0	2.5
	HB9M	56.1	12.7	11.0	16.4	1.1	3.0
Grant Lagoon.....................	GL1M	62.0	14.3	4.3	13.8	2.5	3.0
Miners Point.....................	MP1M	47.5	16.4	12.6	14.2	4.1	2.0

NOTE.--High-purity concentrates were not prepared from the low-grade samples SH1M (Sheep Hill), DM2M and DM3M (Dust Mountain), and HB5M (Halibut Bay).

Most of the chromite is liberated at 28 mesh, the coarsest size evaluated, but the chromite that is disseminated in the olivine lenses is not liberated until about 100 mesh.

BM6M consists of massive chromite with conchoidal fractures and little or no gangue, grading into discrete grains of subhedral chromite in white- to rust-colored olivine. Much of the olivine has altered to pale green serpentine with trace amounts of chlorite and ferromagnesian silicate minerals. Trace amounts of sulfide minerals were noted in the magnetic separation fractions, but no sulfides were observed in hand samples. Most of the chromite is liberated at 35 mesh.

BM7M consists of closely to loosely disseminated, small to relatively large, euhedral chromite crystals in a matrix of olivine, altered olivine, and serpentine, and some banding of the chromite is evident. Minor amounts of ferromagnesian silicate minerals (bronzite-enstatite) are present. Liberation of the chromite is essentially complete at about 48 mesh. Both locking and liberation were noted at finer and coarser sizes, however, because of the wide variation in crystal size of the chromite.

Sheep Hill

SH1M consists of dark- to light-gray massive olivine that contains scattered grains of magnetite. The dark color is apparently due to finely disseminated magnetite. A minor amount of serpentine fills fractures and shows on slickenside surfaces, and external weathered surfaces show the typical buckskin bleaching. Since chromite only occurs in trace amounts, no concentration or liberation data were obtained.

SH2M consists of euhedral chromite grains closely to sparsely disseminated in a matrix of serpentine. Residual olivine is conspicuously present. Banding of both chromite and serpentine-olivine is evident, and serpentine lines fractures and slickensides. Some relatively large, dark-gray clots and lenses of fine-grained, altered olivine contain minor amounts of fine-grained pyrrhotite. The dark-gray portion of the rock gives the impression that the sample contains more chromite than is actually present. Exposed surfaces have been bleached to a buckskin color. Most of the chromite is liberated at minus 65 mesh.

SH3M consists of massive, highly fractured chromite that grades to coarse euhedral chromite crystals abundantly disseminated in olivine. Minor amounts of serpentine occur along slickensides and fractures, and small amounts of chlorite and enstatite are also present. Liberation of chromite in this sample is essentially complete at 28 mesh, the coarsest size examined.

SH4M consists of abundant euhedral grains of chromite closely disseminated in a matrix of olivine with a minor amount of serpentine. Clots of chromite and bands of olivine that are relatively free of chromite are present, as are traces of chlorite and chrysotile. Enstatite is sparsely disseminated as relatively large single crystals and aggregates of single crystals. Slickensides and fracture surfaces are coated with serpentine, and weathered surfaces are stained with iron oxide minerals. Most of the chromite is liberated at 65 mesh.

Dust Mountain

DM1M consists of massive olivine, massive magnetite, and massive chromite, with the latter being least abundant. The olivine contains sparse to abundant disseminations of very fine-grained to coarse euhedral magnetite and chromite crystals. Chromite is disseminated in the magnetite, and small to large clots of olivine are also randomly scattered in the massive magnetite. Minor amounts of diopside and enstatite occur scattered throughout the sample, and serpentine occurs on slickensides and along fractures. The bulk of the chromite appears to be liberated at 28 mesh.

The amount of chromite locked with magnetite was not determined, but the analysis of a minus 65-mesh magnetic concentrate showed that it contained 22.9 pct Cr_2O_3. Scanning electron microscope (SEM) examination revealed that the chromite in this sample is best described as magnesian-chromian hercynite with a composition of about 25 pct Cr_2O_3, 35 pct FeO, 28 pct Al_2O_3, and 10 pct MgO. As may be seen in the two electron micrographs in figure 2, the hercynite (dark gray) contains a relatively large amount of an exsolved phase (light gray) within and along the grain boundaries that is a chromian magnetite with a composition of 75 pct Fe_3O_4, 18 pct Cr_2O_3, 3 pct Al_2O_3, and 1.5 pct MgO. The chromian magnetite also contains about 2.5 pct TiO_2, probably the saturation limit of Ti above which exsolution of an ilmenite phase occurs; no ilmenite was observed. The reason for the low (1.1:1) Cr:Fe ratio in this material becomes obvious from these observations.

DM2M consists of massive olivine with randomly disseminated small euhedral crystals of magnetite and chromite that, in a few areas, have concentrated into bands. Minor amounts of ferromagnesian silicate minerals are present. Serpentine occurs along fractures, and exposed surfaces show the buckskin color. Because of the small size of the chromite grains, the majority of the chromite remains locked with gangue at 200 mesh.

DM3M consists of dark green, fine-grained, massive antigorite that contains a few randomly distributed euhedral grains of magnetite and chromite and minor amounts of olivine and ferromagnesian silicates. Total chromite plus magnetite equals about 1 pct of the rock with approximately equal portions of the two minerals. External surfaces are weathered to the buckskin color. Liberation of the chromite is not complete at 100 mesh. Due to the low-grade nature of the sample, no chromite concentrates were produced.

Figure 3 is an SEM micrograph of a surface field that has fine-grained metallic

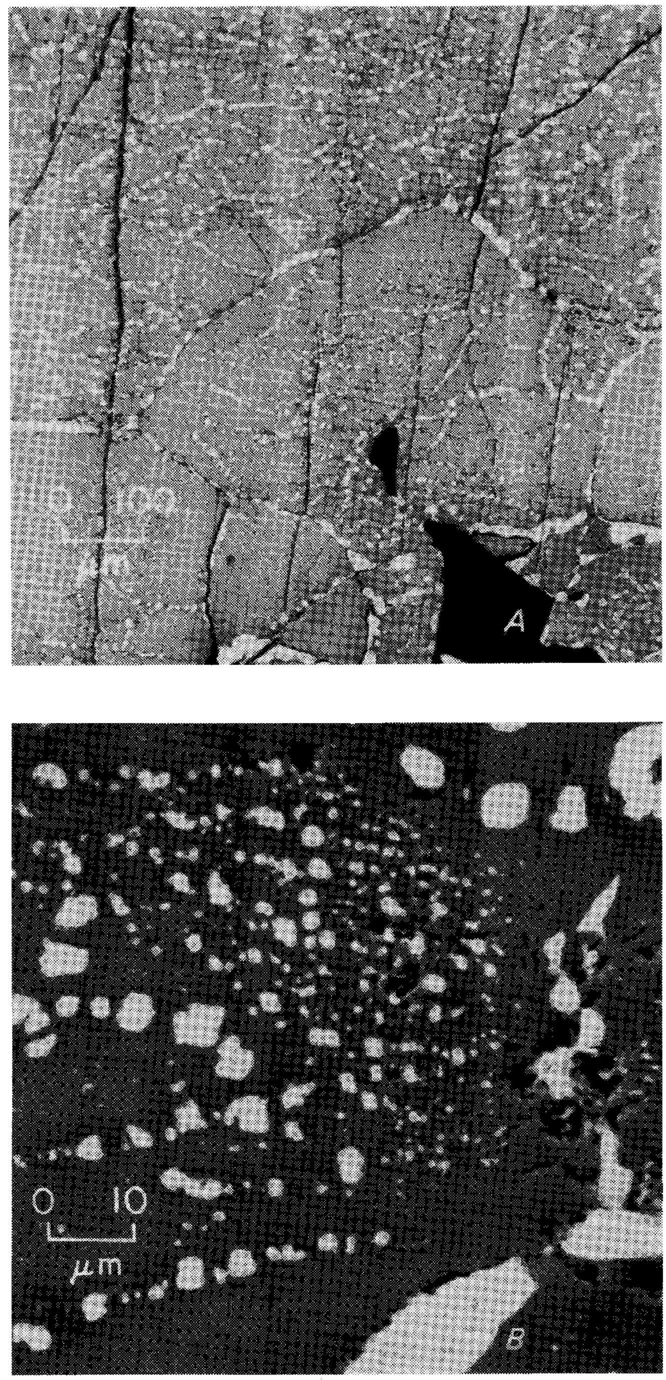

FIGURE 2. - SEM micrographs of sample DM1M from Dust Mountain showing chromian magnetite (light gray) exsolved from chromian hercynite (dark gray) within and along grain boundaries.

particles (small, light particles), initially thought to be a platinum mineral, and a chromite grain (400-µm particle) with magnetite veinlets and overgrowths. SEM analysis showed that the particles are a metallic alloy mineral of Ni and Fe

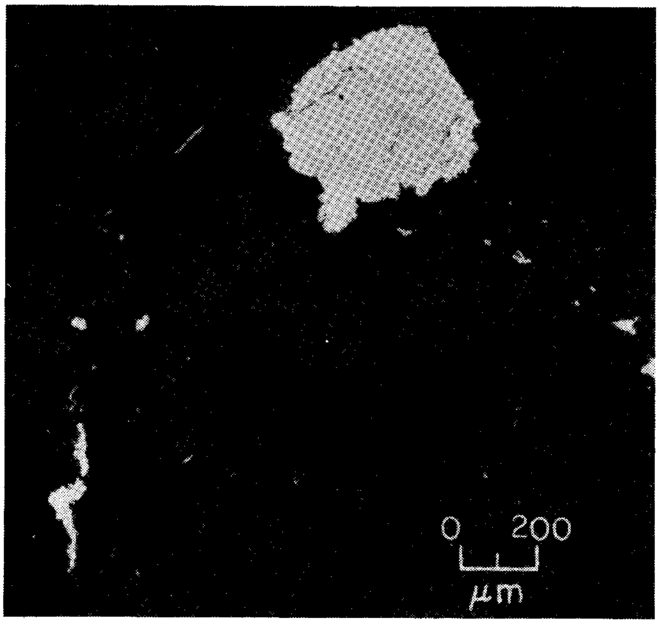

FIGURE 3. - SEM micrograph of sample DM3M from Dust Mountain showing a randomly scattered Ni-Fe alloy mineral (small light particles) and a chromite grain (400-μm particle) with magnetite veinlets and overgrowths. The dark gray and black matrix is serpentine.

with a Ni:Fe ratio of 3:1. The mineral occurs in very small amounts that are randomly distributed throughout the rock. Analysis of the chromite grain, in percent, is 54.2 Cr_2O_3, 20.8 Fe, 6.0 MgO, and 9.1 Al_2O_3, with a Cr:Fe ratio of 1.8:1.

PALMER AREA

Wolverine Complex

WC1M consists primarily of alternately banded chromite and olivine, with associated serpentine and small amounts of kaemmererite. Trace amounts of sulfide minerals were noted in fractions from magnetic separation, but no sulfides were observed in hand samples. The majority of the chromite is liberated at 65 mesh.

KENAI PENINSULA

Red Mountain

RM1M, RM5M, and RM6M consist of subhedral chromite grains disseminated in a dark gray to yellow olivine. The gray color is partly due to minute inclusions of chromite and magnetite. Gray serpentine slickensides are present along fractures in sample RM1M. Stringers of chromite and serpentine are present. Sample RM5M contains more serpentine than the other samples. This sample also contains traces of chlorite and a bright green, ferromagnesian silicate mineral. Some of the chromite grains in sample RM6M have reddish brown alteration rims. Most of the chromite is liberated at 48 mesh, except in sample RM5M, where the liberation size is 65 mesh. These three composite samples were provided by the Anaconda Minerals Co.

RM2M consists of discrete chromite bands separated by chromite-free bands of white to pale yellow olivine. A minor amount of serpentine is also present. Liberation of the chromite is essentially complete at 65 mesh.

RM3M and RM4M consist of medium-sized, discrete grains of subhedral chromite disseminated in white to pale yellow olivine. Some of the chromite is loosely organized into bands and stringers. Trace amounts of a green chromian muscovite surround some of the chromite grains. The few fractures present are filled with brown, soft, iron oxide minerals, and slickensides show serpentine alteration. The chromite is liberated at 48 mesh in both samples.

Windy River

WR1S, WR2S, and WR3S are low-grade placer samples of screened minus 1/2-in material that consist essentially of pebbles of dunite that contain sparsely disseminated chromite. A few pebbles are massive chromite, peridotite, or pyroxenite. Iron oxide minerals occur as coatings on the smaller grains of the samples and as a partial cement in samples WR1S and WR2S. Most of the chromite is locked in the pebbles. Only 60 pct of the chromite present in a minus 28-mesh chromite concentrate was liberated from gangue.

WR4S is a composite of cuttings from 13 drill holes that represent a lens of better grade gravel and was provided by the Anaconda Minerals Co. Screening gave the following size distribution:

Fraction	wt pct
Plus 1/4 in........	30
1/4 in by 28 mesh..	52
Minus 28 mesh......	18

The plus 28-mesh material consists of fragments of basic igneous rocks. About half of the fragments are dunite with very sparsely disseminated chromite. The remainder consists primarily of pebbles of serpentinite, peridotite, pyroxenite, chert, and miscellaneous rock types. The minus 28-mesh material consists of olivine and serpentine with some chromite and magnetic particles. A considerable portion of the chromite remains locked at 65 mesh.

Claim Point

CP1M consists of medium to small, subhedral to anhedral grains of chromite somewhat organized in bands in white to yellowish olivine. Minor amounts of serpentine and iron oxide minerals are present along the few fractures that are present. Most of the chromite is liberated at 100 mesh, but some locking is evident at finer sizes.

CP2M consists of a massive, nonbanded mixture of chromite and white to green olivine with a few random stringers of serpentine. Some chlorite and iron oxide staining occurs on fracture surfaces. Most of the chromite is liberated at 65 mesh.

KODIAK ISLAND

Halibut Bay

HB1M consists of massive olivine with small, disseminated euhedral crystals of chromite and very minor amounts of associated ferromagnesian silicate minerals. Most of the chromite was liberated at 65 mesh.

HB2M consists of banded segregations of massive to disseminated chromite alternating with bands of barren olivine. Minor amounts of serpentine occur along fractures and as very small veins. Most of the chromite is liberated at 65 mesh.

HB3M consists of massive, highly fractured chromite and closely disseminated euhedral chromite crystals in a matrix of altered serpentine. The serpentine is massive, contains some slickensides, and varies from fresh looking to iron stained and altered. Most of the chromite is liberated at 100 mesh, but some remains locked with serpentine in finer sizes.

HB4M cosists of fine- to medium-grained, closely to loosely disseminated euhedral chromite-magnetite in a matrix of altered olivine and serpentine. Some massive chromite-magnetite is present and forms bands in the altered olivine. Medium to relatively large porphyroblastic grains of ferromagnesian silicates are scattered through the rock. A minor amount of chlorite occurs with serpentine on slickenside surfaces. Most of the chromite-magnetite is liberated at 65 mesh, but these two minerals are intimately associated and are not completely liberated even at 200 mesh.

The best chromite concentrate obtained from this sample had the analysis, in percent, shown below in the first column. A mixture of chromite and magnetite that was responsive to a hand magnet was also analyzed, and the results are shown in the second column.

	Chromite	Chromite-Magnetite
Cr_2O_3..........	34.6	32.5
Fe.............	22.1	24.8
MgO............	12.7	12.1
Al_2O_3..........	19.7	19.0
SiO_2...........	3.7	3.6
Cr:Fe ratio....	1.1:1	.9:1

Based on these analyses and on electron microprobe examination, most, if not all, of the chromite grains in this sample have magnetite overgrown on their surfaces. The thickness of the overgrowth varies considerably from grain to grain, but the total amount of magnetite is not large. The iron and chromium content of the chromite is relatively uniform within grains and from grain to grain. Chromite composition is about 45 pct Cr_2O_3, 15 pct Fe, 15 pct Al_2O_3, and 13 pct MgO. Electron micrographs and element distribution maps in figure 4 show typical grains in a minus 65-mesh gravity concentrate that was responsive to a hand magnet. The central grain has a core of chromite with a magnetite overgrowth and olivine gangue attached. Liberation is not complete. Olivine and other silicate minerals also contain intergrown fine-grained magnetite. Similar mineralogy is found in the Miners Point sample (MP1M), discussed later.

HB5M is a pyroxenite with very little chromite and was not examined in detail.

HB6M is brecciated and consists of angular fragments of banded and disseminated massive to euhedral chromite in serpentine with a minor amount of olivine. The rock has been broken and disrupted by fault movement and then recemented. The chromite and serpentine are both highly fractured and granulated. Most of the chromite is liberated at 100 mesh.

HB7M consists of small to medium euhedral chromite crystals closely to loosely disseminated in massive fresh olivine. Chromite bands of variable thickness alternate with narrow bands of pure olivine. Most of the chromite is liberated from gangue at 65 mesh.

HB8M consists of fine to coarse euhedral grains of chromite abundantly disseminated in colorless to gray olivine. Some chromite-barren olivine occurs in bands. A minor amount of iron oxide stain is present on weathered surfaces. Although most of the chromite is liberated at minus 65 mesh, some locking persists through 150 mesh.

HB9M consists of small to medium euhedral crystals of chromite closely disseminated in an olivine matrix. A few clots and occasional bands of olivine occur. Most of the chromite is liberated at 65 mesh.

Grant Lagoon

GL1M consists of fresh and altered serpentine that contains randomly disseminated clots and crystals of chromite and magnetite. Weathered surfaces are very pitted and iron stained. Liberation of the chromite is fairly complete at 65 mesh, but some remains locked at 100 mesh. The amount of chromite locked with magnetite was not determined.

Miners Point

MP1M consists of dark greenish-gray serpentine that contains very sparsely disseminated euhedral chromite-magnetite crystals and random small to large irregular agglomerations of closely disseminated euhedral chromite-magnetite. The magnetite and chromite are optically indeterminable from each other. Minor olivine and ferromagnesian silicate minerals also are present. Most of the chromite is liberated at 100 mesh, although some of the sparsely disseminated chromite is still locked at 150 mesh.

BENEFICIATION PROCEDURE

ROCK SAMPLES

The beneficiation procedure that was used to produce a composite chromite concentrate was basically the same for each of the rock samples and is shown in figure 5. The procedure was modified to suit individual samples.

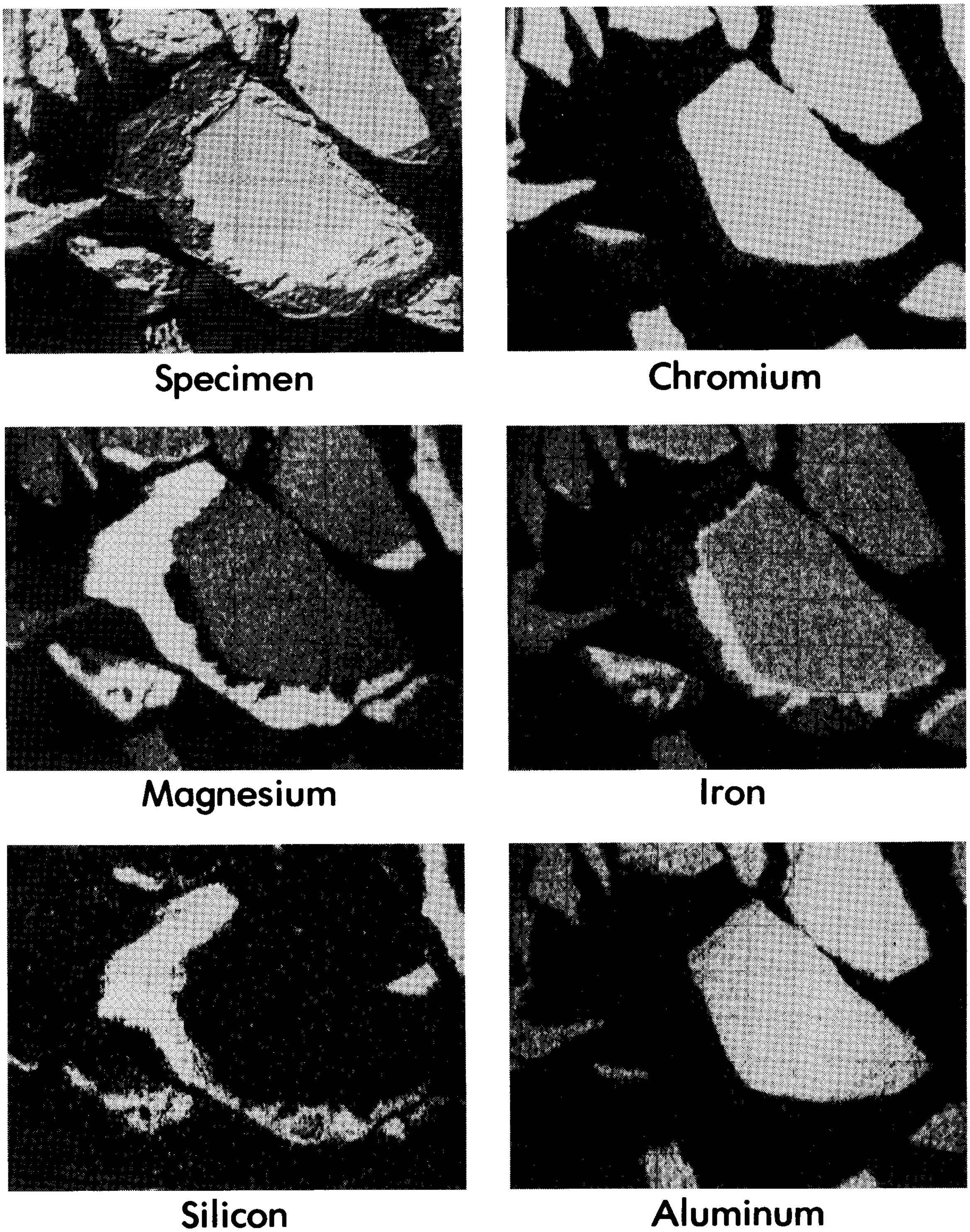

FIGURE 4. - Electron microprobe micrograph and element distribution maps of sample HB4M from Halibut Bay showing magnetite overgrowth on chromite grains. Similar mineralogy is noted in sample MP1M from Miners Point. Grids are 33 μm square.

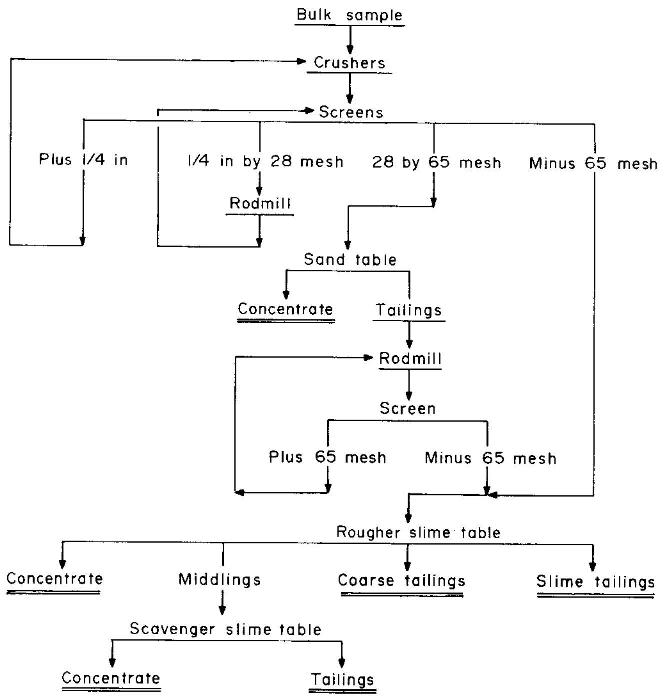

FIGURE 5. - General beneficiation procedure used to concentrate the chromite samples.

The hard-rock samples, as received, consisted of angular rock fragments from 1 to 12 in in the largest dimension. Each sample was crushed in a series of crushers to pass 1/4 in, and a head sample and samples for beneficiation tests were prepared.

The minus 1/4-in material was screened on 28 and 65 mesh. The plus 28-mesh fraction was ground dry in a 13- by 25-in rodmill followed by a 7- by 9-in rodmill to pass 28 mesh and sized on 65 mesh. Grinding was done in stages to minimize production of fines. Generally, the plus 28-mesh fraction from a 20-lb split was ground in the large mill in two stages of 5 and 3 min, and then, if needed, in one to four stages in the small mill to reduce it to minus 28 mesh.

The 28- by 65-mesh fraction was tabled on a 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 several cases, the sample was relatively high grade so that the amount of middlings and coarse tailings was small, or else substantial amounts of chromite were intermixed with the coarse tailings in overlapping bands on the table. When these conditions prevented sharp separation, the middlings and coarse tailings were collected as one product. 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 to improve Cr_2O_3 recovery. The composite chromite concentrates reported in the tables in appendix A are a mathematical combination of the 28- by 65-mesh concentrate and minus 65-mesh rougher and scavenger concentrates.

One sample (DM2M) was very low grade (1.5 pct Cr_2O_3). The entire sample was ground to minus 65 mesh, and a rougher and cleaner step were done rather than the rougher-scavenger sequence shown in figure 5. Three other samples (SH1M, DM3M, and HB5M) were not treated to produce concentrates because of their low chromite content (0.6 to 0.8 pct Cr_2O_3).

PLACER SAMPLES

Four chromite placer samples were received from locations in the Windy River Valley at Red Mountain on the Kenai Peninsula. The river valley drains the Red Mountain ultramafic complex. Three of the samples consisted of screened, minus 1/2-in, unconcentrated river gravel. The fourth sample was a composite of cuttings from 13 drill holes in a fence-drill program across the thickest gravel portion of the valley, as determined by a seismic survey.

Each of the three surface samples was screened on 28 mesh. The minus 28-mesh fraction was tabled to produce a concentrate and tailings. The concentrate was scrubbed in a 10-pct-HCl solution to remove iron oxide surface stain, dried, and then treated electrodynamically and magnetically to produce a final chromite concentrate. The plus 28-mesh fraction was ground to minus 28 mesh and tabled separately in a rougher and a cleaner operation to produce a final concentrate. The composite chromite concentrates reported for these samples in the tables in appendix A are a mathematical combination of the plus 28-mesh cleaner table concentrate and the minus 28-mesh nonmagnetic electrodynamic cleaner concentrate and middlings.

The drill-hole composite sample was screened on 1/4 in and 28 mesh. The plus 1/4-in fraction and the 1/4-in by 28-mesh fraction were ground separately to minus 28 mesh, and each of the three size fractions was tabled in rougher and cleaner steps. To improve Cr_2O_3 recovery, the combined minus 28-mesh cleaner tailings from the three fractions were ground to minus 65 mesh and tabled in a scavenger step. For this sample, the composite chromite concentrate was a mathematical combination of the cleaner table concentrates from the three size fractions and the scavenger concentrate.

RESULTS AND DISCUSSION

The calculated composite chromite concentrates that were produced from deposits along the Border Ranges Fault may be categorized in one of the following groups:

1. High-chromium (metallurgical-grade) chromite that contains a minimum of 46 pct Cr_2O_3 with a Cr:Fe ratio greater than 2.0:1.

2. High-iron (chemical-grade) chromite that contains 40 to 46 pct Cr_2O_3 with a Cr:Fe ratio of 1.5:1 to 2.0:1.

3. Marginal chromite that meets either the grade or the Cr:Fe ratio requirement for one of the classifications above and very nearly meets the other.

4. Submarginal chromite that fails to meet the above classifications.

None of the samples in this study could be classifed as high-aluminum (refractory-grade) or marginal high-aluminum chromite. High-aluminum chromite contains more than 20 pct Al_2O_3 and more than 60 pct Al_2O_3 plus Cr_2O_3. One concentrate (DM1M) from Dust Mountain contained 21.8 pct Al_2O_3, but the Al_2O_3 plus Cr_2O_3 content was only 46.8 pct.

Table 4 summarizes the results of beneficiation on the 38 samples from deposits along the Border Ranges Fault using the procedure in figure 5, and classifies the concentrates according to the above categories. Chromite concentrate grades ranged from 25.0 to 57.8 pct Cr_2O_3, and Cr:Fe ratios ranged from 0.6:1 to 3.1:1. Cr_2O_3 recoveries ranged from 37 to 95 pct. Complete metallurgical balances may be found in tables A-1 through A-35 in appendix A. Three samples (SH1M, DM3M, and HB5M) were very low grade and were not beneficiated.

TABLE 4. - Analyses of chromite concentrates from deposits along the Border Ranges Fault

Location	Sample	Chromite concentrate classification[1]	Analysis, pct					Cr_2O_3 recovery, pct	Cr:Fe ratio
			Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
Tonsina area:									
Bernard Mountain.	BM1M	High Cr........	50.6	13.5	12.1	15.8	2.8	85.1	2.6
	BM2M	High Cr........	49.9	13.7	15.2	15.6	2.0	91.0	2.5
	BM3M	Marg. high Cr..	49.1	17.6	12.8	14.7	1.9	77.6	1.9
	BM4M	Marg. high Cr..	45.9	14.9	17.4	14.6	1.9	82.1	2.1
	BM5M	High Cr........	54.5	14.9	11.0	14.7	2.5	94.4	2.5
	BM6M	High Cr........	53.8	16.6	11.7	13.7	1.8	87.3	2.2
	BM7M	High Cr........	56.8	14.1	9.7	16.0	1.8	84.1	2.8
Sheep Hill.......	SH2M	Marg. high Cr..	51.6	18.4	10.6	12.4	1.8	73.8	1.9
	SH3M	Submarg........	37.2	23.8	18.1	10.9	1.0	95.2	1.1
	SH4M	Marg. high Cr..	49.9	19.2	11.6	12.7	1.8	81.1	1.8
Dust Mountain....	DM1M	Submarg........	25.0	30.3	21.8	11.2	2.3	77.8	.6
	DM2M	Submarg........	35.3	22.7	14.7	13.9	4.8	37.3	1.1
Palmer area:									
Wolverine Complex	WC1M	High Fe........	47.9	20.3	10.4	12.4	2.5	68.0	1.6
Kenai Peninsula:									
Red Mountain.....	RM1M	High Cr........	54.5	16.0	10.2	13.9	1.7	67.4	2.3
	RM2M	High Cr........	54.9	14.5	7.4	15.9	2.2	79.7	2.6
	RM3M	High Cr........	56.8	12.9	8.2	16.7	2.6	88.1	3.0
	RM4M	High Cr........	56.8	14.0	7.4	15.3	2.0	86.7	2.8
	RM5M	High Cr........	52.5	16.0	9.9	15.9	3.5	47.2	2.2
	RM6M	High Cr........	55.5	15.6	10.1	14.1	1.7	77.3	2.4
Windy River......	WR1S	High Fe........	46.8	20.1	9.5	13.1	4.0	60.0	1.6
	WR2S	High Fe........	49.3	19.4	8.7	12.5	3.1	45.5	1.7
	WR3S	Marg. high Fe..	38.8	17.3	8.7	17.5	11.6	43.0	1.5
	WR4S	Marg. high Fe..	43.0	22.4	9.5	13.0	4.2	64.1	1.3
Claim Point......	CP1M	High Cr........	57.8	14.1	8.6	14.8	1.1	63.7	2.8
	CP2M	High Cr........	54.2	14.5	9.0	15.9	2.6	64.0	2.6
Kodiak Island:									
Halibut Bay......	HB1M	High Cr........	50.3	16.9	12.8	15.9	2.3	70.1	2.0
	HB2M	Submarg........	37.1	21.2	15.9	13.9	3.7	73.4	1.2
	HB3M	High Cr........	51.9	11.4	9.2	15.4	4.8	93.9	3.1
	HB4M	Submarg........	29.8	25.0	16.5	12.2	5.8	67.9	.8
	HB6M	High Cr........	47.1	14.6	16.0	15.3	2.4	59.2	2.2
	HB7M	High Cr........	50.4	16.7	12.1	12.5	2.0	83.9	2.1
	HB8M	High Cr........	46.8	13.2	14.8	16.4	2.8	86.7	2.4
	HB9M	High Cr........	54.8	12.3	11.6	17.2	2.4	86.4	3.0
Grant Lagoon.....	GL1M	High Cr........	53.4	15.9	4.0	14.5	4.9	78.3	2.3
Miners Point.....	MP1M	High Fe........	41.5	19.1	10.9	13.7	4.6	80.1	1.5

[1]High Cr--high chromium; Marg. high Cr--marginal high chromium; High Fe--high iron; Marg. high Fe--marginal high iron; Submarg.--submarginal.

NOTE.--Samples SH1M (Sheep Hill), DM3M (Dust Mountain), and HB5M (Halibut Bay) were very low grade and were not beneficiated.

Twenty of the samples were beneficiated to produce high-chromium chromite concentrates. The concentrate from sample CP1M from Claim Point had the highest grade, 57.8 pct Cr_2O_3, and 17 of the 20 concentrates had grades in excess of 50 pct Cr_2O_3. The concentrate from sample HB3M from Halibut Bay had the best Cr:Fe ratio, 3.1:1, and 10 other concentrates had ratios of 2.5:1 or better.

Two samples from Bernard Mountain and two from Sheep Hill were beneficiated to produce marginal high-chromium chromite concentrates. Three of the four concentrates had grades in excess of 46 pct Cr_2O_3, but their Cr:Fe ratios were only 1.8:1 and 1.9:1. The fourth sample had a Cr:Fe ratio of 2.1:1, but the grade was only 45.9 pct Cr_2O_3.

Six samples were beneficiated to produce high-iron or marginal high-iron chromite concentrates. Four of the samples were from the Windy River placer deposits. The six concentrates ranged in grade from 38.8 to 49.3 pct Cr_2O_3, and the Cr:Fe ratios ranged from 1.3:1 to 1.7:1.

Five of the concentrates were classified as submarginal chromites because of low grade and low Cr:Fe ratio. Results of the beneficiation tests indicate that none of these concentrates can be substantially improved by gravity separation.

The mineralogy of the 38 samples indicates that they contain various amounts of magnetics removable with a hand magnet. A magnetic separation step could have been used to improve the Cr:Fe ratio of those gravity concentrates that contained significant amounts of magnetic material. However, the improved grade and Cr:Fe ratio would have been at the expense of chromite recovery.

The coarse rougher and scavenger tailings from several samples contained recoverable chromite. Some of the chromite was lost because of locking at minus 65 mesh. Further grinding could have liberated the locked chromite and improved recovery. In some cases, however, techniques other than gravity concentration, such as high-intensity magnetic separation or electrodynamic separation, could have been used to improve recovery of liberated chromite from the coarse tailings.

The slime tailings from these samples represented a loss of 2 to 19 pct of the chromite. Although this chromite was lost during tabling, some of it could have been recovered by gravity separation techniques better suited for fine-particle recovery. Chromite loss in the slime tailings was less than 10 pct in all but four of the samples, so methods for recovering the fine chromite were not investigated in this study.

The head samples and the rougher table concentrates from each test were analyzed for precious metals content. Most of the samples contained no detectable platinum, palladium, or gold. Table 5 shows the precious metals analyses of those head samples or gravity concentrates that contained detectable precious metals. Sample DM1M from Dust Mountain contained as much as 0.03 oz/ton Pt and 0.03 oz/ton Pd in the head sample. The gravity concentrate from that sample also contained 0.03 oz/ton Pt and 0.03 oz/ton Pd.

TABLE 5. - Precious metal analyses, ounce per ton

Location	Sample	Head sample			Gravity concentrate		
		Pt	Pd	Au	Pt	Pd	Au
Tonsina area:							
Bernard Mountain..........	BM2M	<0.0006	<0.0006	<0.0004	<0.004	0.033	0.002
	BM4M	<.0006	<.0006	<.0004	<.004	<.004	.002
	BM7M	<.0006	<.0006	<.0004	<.004	<.004	.080
Sheep Hill................	SH2M	.008	<.0006	<.001	.010	<.004	.002
	SH3M	.004	.002	<.0004	.004	.001	<.001
	SH4M	.008	<.0004	<.0004	<.004	<.004	<.0008
Dust Mountain.............	DM1M	.035	.032	<.0004	.032	.033	<.001
	DM2M	<.0006	<.0006	<.0004	.005	.006	.002
	DM3M	<.0006	<.0006	.002	([1])	([1])	([1])
Palmer area:							
Wolverine Complex.........	WC1M	.01	<.01	<.002	.004	<.002	<.0008
Kenai Peninsula:							
Red Mountain..............	RM4M	<.01	<.01	<.002	<.002	<.002	.0009
Windy River...............	WR4S	.001	<.001	<.0004	.002	<.001	<.0004
Claim Point...............	CP2M	<.01	<.01	<.002	.034	.072	.002
Kodiak Island:							
Halibut Bay...............	HB1M	<.0006	<.0006	.001	<.004	<.004	<.0008
Grant Lagoon..............	GL1M	<.004	<.004	<.0008	<.002	<.002	.005
Miners Point..............	MP1M	<.004	<.004	<.0008	<.002	<.002	.001

[1]Very low-grade sample; not beneficiated.

NOTE.--Samples not listed in this table had precious metals analyses below detectable limits in both the head sample and the gravity concentrate.

SUMMARY AND CONCLUSIONS

Thirty-eight samples of chromite-bearing materials were collected from deposits along the Border Ranges Fault in southern Alaska. These samples were characterized mineralogically and beneficiated by gravity separation to produce chromite concentrates.

The samples were high-graded from chromite-bearing areas in ultramafic and mafic-ultramafic rock complexes. They are peridotites and chromitites that consist primarily of massive to disseminated chromite in a matrix of olivine and serpentine. Minor constituents include magnetic minerals removable with a hand magnet, chlorite, ferromagnesian silicates, and sulfides.

A beneficiation procedure that included grinding, sizing, and gravity separation was designed to treat the samples. Twenty-four samples were beneficiated to produce high-chromium (metallurgical-grade) or marginal high-chromium chromite concentrates. Six samples were beneficiated to produce high-iron (chemical-grade) or marginal high-iron chromite concentrates. Five samples were classified as submarginal chromites, and three samples were not beneficiated because they were too low in grade. Chromium recoveries from those samples that were treated ranged from 37 to 95 pct.

The potential for platinum association with the chromite was investigated. No platinum-group minerals were observed in the mineralogical examinations. Sixteen samples contained detectable concentrations of platinum or palladium in the head sample or gravity concentrate. One head sample and two gravity concentrates contained 0.03 oz/ton Pt; the others had no more than 0.01 oz/ton.

This investigation was an evaluation of the chromite and platinum resource potential of the Border Ranges Fault in southern Alaska. Although all of the rock samples were high-graded from surface exposures, the information from field measurements (discussed in part 1) and from mineralogy and beneficiation studies indicates that these deposits may be significant chromium resources. Based on an identified resource compilation from part 1 of 2.5 million tons Cr_2O_3,[8] the deposits contain enough chromite to meet U.S. demand for 4 years, based on 1981 consumption.[9]

The precious metal analyses of the 38 chromite samples studied do not indicate that these materials represent good platinum resources. However, the platinum content of the samples from Sheep Hill, Dust Mountain, the Wolverine Complex, and Claim Point may indicate potential target areas for future platinum-group metal exploration.

[8]Work cited in footnote 7.

[9]Work cited in footnote 3.

APPENDIX A.--METALLURGICAL BALANCES

TABLE A-1. - Gravity table concentration of sample BM1M from Bernard Mountain

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]	10.9	50.4	12.7	12.5	15.8	2.7	13.7	2.7
Minus 65-mesh:								
Rougher concentrate*[2]	45.3	51.2	13.8	12.1	15.5	2.4	57.6	2.5
Rougher middlings and coarse tailings	32.1	25.5					20.4	
Scavenger concentrate*	11.5	48.2	13.2	11.7	17.1	4.5	13.8	2.5
Scavenger tailings	20.6	12.9					6.6	
Rougher slime tailings	11.7	28.5					8.3	
Composite or total	100.0	40.2					100.0	
Calculated composite concentrate[1]	67.7	50.6	13.5	12.1	15.8	2.8	85.1	2.6

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.0006; Pd <0.0006; Au <0.0004; Ag <0.02.

NOTE.--Blank entry means data not available.

TABLE A-2. - Gravity table concentration of sample BM2M from Bernard Mountain

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]	31.0	49.2	13.3	15.4	15.5	2.0	36.3	2.5
Minus 65-mesh:								
Rougher concentrate*[3]	37.6	50.5	14.1	15.0	15.6	1.8	45.1	2.4
Rougher middlings and coarse tailings	23.0	26.0					14.3	
Scavenger concentrate*	8.1	49.6	13.1	15.3	15.6	2.6	9.6	2.6
Scavenger tailings	14.9	13.2					4.7	
Rougher slime tailings	8.4	21.6					4.3	
Composite or total	100.0	42.0					100.0	
Calculated composite concentrate[1]	76.7	49.9	13.7	15.2	15.6	2.0	91.0	2.5

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.004; Pd 0.015; Au 0.003; Ag 0.01.
[3]Precious metals analysis, oz/ton: Pt <0.004; Pd 0.051; Au 0.002; Ag 0.01.

NOTE.--Blank entry means data not available.

TABLE A-3. - Gravity table concentration of sample BM3M from Bernard Mountain

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	4.6	48.8	17.6	12.8	14.8	2.2	8.8	1.9
Minus 65-mesh:								
Rougher concentrate*[3].......	33.4	49.2	17.6	12.8	14.7	1.8	64.3	1.9
Rougher middlings...........	16.0	23.9					15.0	
Scavenger concentrate*....	2.4	47.7	17.3	12.0	15.2	3.1	4.5	1.9
Scavenger tailings........	13.6	19.7					10.5	
Rougher coarse tailings.....	30.6	4.2					5.0	
Rougher slime tailings......	15.4	11.4					6.9	
Composite or total........	100.0	25.5					100.0	
Calculated composite concentrate[1].............	40.4	49.1	17.6	12.8	14.7	1.9	77.6	1.9

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.004; Pd <0.004; Au <0.0008; Ag <0.01.
[3]Precious metals analysis, oz/ton: Pt <0.004; Pd <0.004; Au 0.0009; Ag <0.01.

NOTE.--Blank entry means data not available.

TABLE A-4. - Gravity table concentration of sample BM4M from Bernard Mountain

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	10.4	45.4	14.9	17.6	14.5	1.8	17.9	2.1
Minus 65-mesh:								
Rougher concentrate*[2].......	28.8	47.2	15.1	17.6	13.9	1.2	51.4	2.1
Rougher middlings and coarse tailings..................	44.2	14.1					23.6	
Scavenger concentrate*....	8.1	41.8	14.2	16.3	17.0	4.8	12.8	2.0
Scavenger tailings........	36.1	7.9					10.8	
Rougher slime tailings......	16.6	11.3					7.1	
Composite or total........	100.0	26.4					100.0	
Calculated composite concentrate[1].............	47.3	45.9	14.9	17.4	14.6	1.9	82.1	2.1

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.004; Pd <0.004; Au 0.002; Ag 0.01.

NOTE.--Blank entry means data not available.

TABLE A-5. - Gravity table concentration of sample BM5M from Bernard Mountain

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	43.1	54.5	14.7	11.1	15.1	2.8	48.4	2.5
Minus 65-mesh:								
Rougher concentrate*[2].......	38.3	55.1	15.1	11.0	14.1	1.8	43.5	2.5
Rougher middlings and coarse tailings..................	12.7	17.2					4.5	
Scavenger concentrate*....	2.6	46.9	13.7	9.6	18.0	7.4	2.5	2.3
Scavenger tailings........	10.1	9.5					2.0	
Rougher slime tailings......	5.9	30.0					3.6	
Composite or total........	100.0	48.5					100.0	
Calculated composite concentrate[1]............	84.0	54.5	14.9	11.0	14.7	2.5	94.4	2.5

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.001; Pd <0.001; Au <0.0008; Ag <0.04.

NOTE.--Blank entry means data not available.

TABLE A-6. - Gravity table concentration of sample BM6M from Bernard Mountain

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	17.1	53.1	17.0	11.8	13.6	1.7	25.0	2.1
Minus 65-mesh:								
Rougher concentrate*[2].......	36.6	54.7	16.6	11.7	13.5	1.6	55.3	2.3
Rougher middlings and coarse tailings..................	36.2	15.2					15.1	
Scavenger concentrate*....	5.1	49.7	15.8	11.3	15.5	3.2	7.0	2.2
Scavenger tailings........	31.1	9.5					8.1	
Rougher slime tailings......	10.1	16.5					4.6	
Composite or total........	100.0	36.3					100.0	
Calculated composite concentrate[1]...........	58.8	53.8	16.6	11.7	13.7	1.8	87.3	2.2

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.001; Pd <0.001; Au <0.0008; Ag 0.01.

NOTE.--Blank entry means data not available.

TABLE A-7. - Gravity table concentration of sample BM7M from Bernard Mountain

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	10.0	57.4	14.4	9.8	14.8	1.4	20.4	2.7
Minus 65-mesh:								
Rougher concentrate*[3].......	28.2	56.9	14.1	9.8	16.1	1.7	57.2	2.8
Rougher middlings...........	14.3	25.9						
Scavenger concentrate*....	3.4	53.6	13.4	8.7	19.2	4.2	6.5	2.7
Scavenger tailings........	10.9	17.2					6.7	
Rougher coarse tailings.....	32.1	3.0					3.4	
Rougher slime tailings......	15.4	10.6					5.8	
Composite or total........	100.0	28.1					100.0	
Calculated composite concentrate[1]............	41.6	56.8	14.1	9.7	16.0	1.8	84.1	2.8

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.004; Pd <0.004; Au 0.001; Ag <0.01.
[3]Precious metals analysis, oz/ton: Pt <0.004; Pd <0.004; Au 0.160; Ag 0.05.

NOTE.--Blank entry means data not available.

TABLE A-8. - Gravity table concentration of sample SH2M from Sheep Hill

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	8.2	51.1	18.2	10.6	12.8	1.9	16.7	1.9
Minus 65-mesh:								
Rougher concentrate*[3].......	24.3	52.4	18.6	10.7	11.9	1.4	50.7	1.9
Rougher middlings and coarse tailings...................	53.3	12.7					27.1	
Scavenger concentrate*....	3.4	46.9	17.3	9.7	15.0	4.6	6.4	1.9
Scavenger tailings........	49.9	10.4					20.7	
Rougher slime tailings......	14.2	9.7					5.5	
Composite or total........	100.0	25.1					100.0	
Calculated composite concentrate[1]............	35.9	51.6	18.4	10.6	12.4	1.8	73.8	1.9

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt 0.010; Pd 0.005; Au 0.003; Ag 0.01.
[3]Precious metals analysis, oz/ton: Pt 0.011; Pd <0.004; Au 0.002; Ag 0.01.

NOTE.--Blank entry means data not available.

TABLE A-9. - Gravity table concentration of sample SH3M from Sheep Hill

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	42.9	37.3	23.8	18.4	10.8	0.9	44.1	1.1
Minus 65-mesh:								
Rougher concentrate*[3].......	44.5	37.3	23.8	17.9	10.9	1.0	45.6	1.1
Rougher middlings and coarse tailings..................	7.6	30.0					6.3	
Scavenger concentrate*....	5.6	35.8	23.3	17.7	11.7	2.4	5.5	1.1
Scavenger tailings........	2.0	13.7					.8	
Rougher slime tailings......	5.0	28.9					4.0	
Composite or total........	100.0	36.3					100.0	
Calculated composite concentrate[1]............	93.0	37.2	23.8	18.1	10.9	1.0	95.2	1.1

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt 0.003; Pd 0.001; Au <0.0004; Ag <0.02.
[3]Precious metals analysis, oz/ton: Pt 0.005; Pd 0.001; Au 0.001; Ag <0.02.

NOTE.--Blank entry means data not available.

TABLE A-10. - Gravity table concentration of sample SH4M from Sheep Hill

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	6.4	49.6	19.1	12.0	13.4	2.4	11.3	1.8
Minus 65-mesh:								
Rougher concentrate*[2].......	35.1	50.1	19.3	11.6	12.5	1.6	62.8	1.8
Rougher middlings...........	14.2	31.1					15.8	
Scavenger concentrate*....	4.0	48.9	18.9	11.3	13.2	2.4	7.0	1.8
Scavenger tailings........	10.2	24.1					8.8	
Rougher coarse tailings.....	31.8	3.5					4.0	
Rougher slime tailings......	12.5	13.8					6.1	
Composite or total........	100.0	28.0					100.0	
Calculated composite concentrate[1]............	45.5	49.9	19.2	11.6	12.7	1.8	81.1	1.8

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.004; Pd <0.004; Au <0.0008; Ag <0.01.

NOTE.--Blank entry means data not available.

TABLE A-11. - Gravity table concentration of sample DM1M from Dust Mountain

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	9.1	23.6	30.1	20.1	9.7	1.4	12.2	0.5
Minus 65-mesh:								
Rougher concentrate*[3].......	41.5	24.4	30.1	20.4	10.0	1.7	57.5	.6
Rougher middlings and coarse tailings..................	36.4	10.5						
Scavenger concentrate*....	7.4	22.5	29.6	20.7	11.1	3.0	9.4	.5
Scavenger middlings.......	29.0	7.5					12.3	
Rougher slime tailings......	13.0	11.7					8.6	
Composite or total........	100.0	17.6					100.0	
Calculated composite concentrate[1].............	58.0	24.0	30.0	20.4	10.1	1.8	79.1	.5

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt 0.031; Pd 0.032; Au <0.0008; Ag 0.01.
[3]Precious metals analysis, oz/ton: Pt 0.046; Pd 0.041; Au 0.001; Ag 0.01.

NOTE.--Blank entry means data not available.

TABLE A-12. - Gravity table concentration of sample DM2M from Dust Mountain

Product	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
Minus 65-mesh:								
Rougher concentrate.........	10.6	8.5					59.3	
Cleaner concentrate[1]......	1.6	35.3	22.7	14.7	13.9	4.8	37.3	1.1
Cleaner tailings[2].........	9.0	3.7					22.0	
Rougher coarse tailings.....	65.5	.5					21.7	
Rougher slime tailings......	23.9	1.2					19.0	
Composite or total........	100.0	1.5					100.0	

[1]Precious metals analysis, oz/ton: Pt 0.006; Pd 0.006; Au 0.002; Ag <0.02.
[2]Precious metals analysis, oz/ton: Pt <0.0006; Pd <0.0006; Au <0.0004; Ag <0.02.

NOTE.--Blank entry means data not available.

TABLE A-13. - Gravity table concentration of sample WC1M from the Wolverine Complex

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	3.2	46.2	20.0	10.9	13.4	3.3	7.2	1.6
Minus 65-mesh:								
Rougher concentrate*[3].......	22.7	48.7	20.5	10.4	11.8	2.0	54.2	1.6
Rougher middlings...........	19.9	20.0					19.4	
Scavenger concentrate*....	3.1	43.7	19.6	9.6	15.6	4.9	6.6	1.5
Scavenger tailings........	16.8	15.6					12.8	
Rougher coarse tailings.....	39.0	4.4					8.4	
Rougher slime tailings......	15.2	14.5					10.8	
Composite or total........	100.0	20.4					100.0	
Calculated composite concentrate[1].............	29.0	47.9	20.3	10.4	12.4	2.5	68.0	1.6

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt 0.008; Pd <0.003; Au <0.0008; Ag 0.02.
[3]Precious metals analysis, oz/ton: Pt <0.001; Pd <0.001; Au <0.0008; Ag 0.01.

NOTE.--Blank entry means data not available.

TABLE A-14. - Gravity table concentration of composite RM1M from Red Mountain

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	1.6	51.9	17.3	9.4	15.0	3.2	9.7	2.1
Minus 65-mesh:								
Concentrate*[2]...............	9.0	55.0	15.8	10.4	13.7	1.4	57.7	2.4
Middlings..................	4.3	25.4					12.7	
Coarse tailings............	76.5	1.8					16.0	
Slime tailings..............	8.6	3.9					3.9	
Composite or total........	100.0	8.6					100.0	
Calculated composite concentrate[1].............	10.6	54.5	16.0	10.2	13.9	1.7	67.4	2.3

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analyses for Pt, Pd, Au, and Ag were not done to these products.

NOTE.--Blank entry means data not available.

TABLE A-15. - Gravity table concentration of sample RM2M from Red Mountain deposit 24

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	8.7	54.1	14.3	7.3	16.5	3.0	15.7	2.6
Minus 65-mesh:								
Rougher concentrate*[3].......	33.0	55.4	14.6	7.5	15.6	1.8	60.8	2.6
Rougher middlings...........	13.1	28.4					12.4	
Scavenger concentrate*....	1.9	51.0	13.6	6.6	18.9	4.8	3.2	2.6
Scavenger tailings........	11.2	24.6					9.2	
Rougher coarse tailings.....	31.9	6.4					6.8	
Rougher slime tailings......	13.3	9.6					4.3	
Composite or total........	100.0	30.0					100.0	
Calculated composite concentrate[1].............	43.6	54.9	14.5	7.4	15.9	2.2	79.7	2.6

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.002; Pd <0.002; Au 0.0013; Ag <0.01.
[3]Precious metals analysis, oz/ton: Pt <0.002; Pd <0.002; Au <0.0004; Ag <0.01.

NOTE.--Blank entry means data not available.

TABLE A-16. - Gravity table concentration of sample RM3M from Red Mountain deposit 9

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	15.3	57.4	13.1	8.5	16.1	1.8	22.1	3.0
Minus 65-mesh:								
Rougher concentrate*[2].......	41.0	56.6	12.8	8.2	16.8	2.9	58.2	3.0
Rougher middlings and coarse tailings..................	33.7	19.0					16.1	
Scavenger concentrate*....	5.5	56.3	12.7	7.8	17.5	2.4	7.8	3.0
Scavenger tailings........	28.2	11.7					8.3	
Rougher slime tailings......	10.0	14.4					3.6	
Composite or total........	100.0	39.8					100.0	
Calculated composite concentrate[1].............	61.8	56.8	12.9	8.2	16.7	2.6	88.1	3.0

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.002; Pd <0.002; Au <0.001; Ag <0.01.

NOTE.--Blank entry means data not available.

TABLE A-17. - Gravity table concentration of sample RM4M from Red Mountain deposit 9

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	11.3	55.0	14.2	6.8	15.8	2.9	27.6	2.6
Minus 65-mesh:								
Rougher concentrate*[3].......	21.5	57.7	13.9	7.7	14.8	1.4	55.0	2.8
Rougher middlings...........	12.5	16.0					8.9	
Scavenger concentrate*....	1.6	57.9	14.4	6.7	17.5	4.2	4.1	2.8
Scavenger tailings........	10.9	9.9					4.8	
Rougher coarse tailings.....	44.9	2.9					5.8	
Rougher slime tailings......	9.8	6.2					2.7	
Composite or total........	100.0	22.5					100.0	
Calculated composite concentrate[1]............	34.4	56.8	14.0	7.4	15.3	2.0	86.7	2.8

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.002; Pd <0.002; Au 0.001; Ag <0.01.
[3]Precious metals analysis, oz/ton: Pt <0.002; Pd <0.002; Au 0.0008; Ag <0.01.

NOTE.--Blank entry means data not available.

TABLE A-18. - Gravity table concentration of composite RM5M from Red Mountain

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	0.5	47.2	15.5	9.0	19.4	7.1	4.9	2.1
Minus 65-mesh:								
Concentrate*[2]..............	3.8	53.2	16.1	10.0	15.4	3.0	42.3	2.3
Middlings..................	7.9	20.4					33.7	
Coarse tailings.............	77.3	.9					14.5	
Slime tailings..............	10.5	2.1					4.6	
Composite or total........	100.0	4.8					100.0	
Calculated composite concentrate[1]............	4.3	52.5	16.0	9.9	15.9	3.5	47.2	2.2

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analyses for Pt, Pd, Au, and Ag were not done to these products.

NOTE.--Blank entry means data not available.

TABLE A-19. - Gravity table concentration of composite RM6M from Red Mountain

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	2.3	54.2	16.1	9.7	14.7	2.5	13.1	2.3
Minus 65-mesh:								
Concentrate*[2]...............	11.0	55.8	15.5	10.2	14.0	1.5	64.2	2.5
Middlings..................	5.0	20.4					10.7	
Coarse tailings............	69.1	1.2					8.7	
Slime tailings..............	12.6	2.5					3.3	
Composite or total........	100.0	9.5					100.0	
Calculated composite concentrate[1]............	13.3	55.5	15.6	10.1	14.1	1.7	77.3	2.4

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analyses for Pt, Pd, Au, and Ag were not done to these products.

NOTE.--Blank entry means data not available.

TABLE A-20. - Concentration of placer sample WR1S from the Windy River

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
Plus 28-mesh fraction ground to minus 28 mesh....................	71.6	1.4					33.4	
Cleaner table concentrate*.......	.6	45.9	21.8	9.4	14.0	3.5	9.5	1.4
Cleaner table tailings...........	25.8	1.9					16.9	
Rougher table coarse tailings....	37.6	.4					5.2	
Rougher table slime tailings.....	7.6	.7					1.8	
Minus 28-mesh fraction............	28.4	6.8					66.6	
Table concentrate................	7.8	23.1					62.3	
Nonmagnetic electrodynamic cleaner concentrate*.........	1.1	49.8	21.3	10.5	10.3	1.1	19.0	1.6
Nonmagnetic electrodynamic cleaner middlings*...........	2.0	45.5	18.9	8.9	14.3	5.7	31.5	1.6
Magnetic reject................	.4	34.8	30.3				4.8	
Electrodynamic cleaner tailings	1.0	9.8					3.4	
Electrodynamic rougher tailings	3.3	3.2					3.6	
Table tailings..................	20.6	.6					4.3	
Composite or total............	100.0	2.9					100.0	
Calculated composite concentrate[1]................	3.7	46.8	20.1	9.5	13.1	4.0	60.0	1.6

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.

NOTE.--Blank entry means data not available. Concentrates were not analyzed for Pt, Pd, Au, and Ag because analyses from preliminary tests were below detection limits.

TABLE A-21. - Concentration of placer sample WR2S from the Windy River

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
Plus 28-mesh fraction ground to minus 28 mesh	76.1	3.3					53.3	
Cleaner table concentrate*	1.2	49.7	19.1	8.2	14.8	3.0	12.5	1.8
Cleaner table tailings	25.0	6.0					31.5	
Rougher table coarse tailings	40.6	.8					6.8	
Rougher table slime tailings	9.3	1.3					2.5	
Minus 28-mesh fraction	23.9	9.3					46.7	
Table concentrate	7.3	29.0					44.3	
Nonmagnetic electrodynamic cleaner concentrate*	1.4	51.2	21.1	8.9	9.1	.9	15.0	1.7
Nonmagnetic electrodynamic cleaner middlings*	1.8	47.6	18.3	8.9	13.7	4.9	18.0	1.8
Magnetic reject	.9	37.3	29.0				7.0	
Electrodynamic cleaner tailings	.6	11.2					1.4	
Electrodynamic rougher tailings	2.6	5.3					2.9	
Table tailings	16.6	.7					2.4	
Composite or total	100.0	4.8					100.0	
Calculated composite concentrate[1]	4.4	49.3	19.4	8.7	12.5	3.1	45.5	1.7

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.

NOTE.--Blank entry means data not available. Concentrates were not analyzed for Pt, Pd, Au, and Ag because analyses from preliminary tests were below detection limits.

TABLE A-22. - Concentration of placer sample WR3S from the Windy River

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
Plus 28-mesh fraction ground to minus 28 mesh	54.5	0.9					20.9	
Cleaner table concentrate*	.2	42.8	23.7	8.4	13.8	3.5	3.5	1.2
Cleaner table tailings	10.7	2.7					11.8	
Rougher table coarse tailings	36.7	.3					4.5	
Rougher table slime tailings	6.9	.4					1.1	
Minus 28-mesh fraction	45.5	4.2					79.0	
Table concentrate	11.9	15.1					73.5	
Nonmagnetic electrodynamic cleaner concentrate*	.3	49.0	21.1	10.7	10.8	1.9	6.0	1.6
Nonmagnetic electrodynamic cleaner middlings*	2.2	37.0	16.2	8.5	18.8	13.6	33.5	1.6
Magnetic reject	1.4	33.5	27.5				19.2	
Electrodynamic cleaner tailings	1.3	2.2					1.2	
Electrodynamic rougher tailings	6.7	5.0					13.7	
Table tailings	33.6	.4					5.5	
Composition or total	100.0	2.4					100.0	
Calculated composite concentrate[1]	2.7	38.8	17.3	8.7	17.5	11.6	43.0	1.5

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.

NOTE.--Blank entry means data not available. Concentrates were not analyzed for Pt, Pd, Au, and Ag because analyses from preliminary tests were below detection limits.

TABLE A-23. - Gravity table concentration of placer composite WR4S from the Windy River

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
Plus 1/4-in fraction ground to minus 28 mesh	30.4	0.9					17.5	
Cleaner concentrate*	.1	44.3	21.5	8.2	15.0	4.3	4.9	1.4
Cleaner tailings	5.3	2.4					7.0	
Rougher coarse tailings	22.0	.4					4.9	
Rougher slime tailings	3.0	.4					.7	
1/4-in by 28-mesh fraction ground to minus 28 mesh	52.2	1.3					36.6	
Cleaner concentrate*	.3	44.6	21.7	8.2	13.9	4.0	7.4	1.4
Cleaner tailings	10.0	3.2					17.7	
Rougher coarse tailings	36.5	.5					10.0	
Rougher slime tailings	5.4	.5					1.5	
Minus 28-mesh fraction	17.4	4.8					45.9	
Cleaner concentrate*[2]	.8	46.9	23.4	9.7	11.1	2.0	20.7	1.4
Cleaner tailings[2]	5.3	7.6					22.1	
Rougher tailings	11.3	.5					3.1	
Combined cleaner tailings ground to minus 65 mesh	20.6	4.1					46.8	
Scavenger concentrate*	1.4	40.3	22.1	9.8	13.7	5.5	31.1	1.2
Scavenger coarse tailings	17.3	1.4					13.4	
Scavenger slime tailings	1.9	2.2					2.3	
Composite or total	100.0	1.8					100.0	
Calculated composite concentrate[1]	2.7	43.0	22.4	9.5	13.0	4.2	64.1	1.3

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt 0.002; Pd <0.001; Au <0.0004; Ag <0.02.

NOTE.--Blank entry means data not available.

TABLE A-24. - Gravity table concentration of sample CP1M from Claim Point deposit 10

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
Minus 65-mesh:								
Rougher concentrate*[2]	23.6	57.8	14.1	8.6	14.8	1.1	63.7	2.8
Rougher middlings	63.4	10.0					29.5	
Scavenger concentrate*	4.4	56.8	13.5	8.7	16.5	2.2	11.7	2.9
Scavenger tailings	59.0	6.5	4.5	.9	54.5	37.0	17.0	
Rougher slime tailings	13.0	11.2					6.8	
Composite or total	100.0	21.4					100.0	
Calculated composite concentrate[1]	28.0	57.6	14.0	8.6	15.1	1.3	75.4	2.8

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.01; Pd <0.01; Au <0.002; Ag <0.1.

NOTE.--Blank entry means data not available.

TABLE A-25. - Gravity table concentration of sample CP2M from Claim Point deposit 15

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
Minus 65-mesh:								
Rougher concentrate*[2]....	23.6	54.9	14.6	9.2	15.4	2.3	41.3	2.6
Rougher middlings........	64.3	24.4					50.0	
Scavenger concentrate*.	13.5	52.9	14.4	8.7	16.7	3.2	22.7	2.6
Scavenger middlings....	47.4	16.9					25.5	
Scavenger tailings.....	3.4	16.4					1.8	
Rougher slime tailings...	12.1	22.5					8.7	
Composite or total.....	100.0	31.4					100.0	
Calculated composite concentrate[1]..........	37.1	54.2	14.5	9.0	15.9	2.6	64.0	2.6

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt 0.034; Pd 0.072; Au 0.002; Ag 0.08.

NOTE.--Blank entry means data not available.

TABLE A-26. - Gravity table concentration of sample HB1M from Halibut Bay

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
Minus 65 mesh:								
Cleaner concentrate[1].....	33.3	50.3	16.9	12.8	15.9	2.3	70.1	2.0
Rougher middlings and cleaner tailings........	43.2	9.5					17.2	
Rougher slime tailings...	23.5	12.9					12.7	
Composite or total.....	100.0	23.9					100.0	

[1]Precious metals analysis, oz/ton: Pt <0.004; Pd <0.004; Au <0.0008; Ag 0.02.

NOTE.--Blank entry means data not available.

TABLE A-27. - Gravity table concentration of sample HB2M from Halibut Bay

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]	1.8	36.5	20.6	15.8	14.5	4.3	3.9	1.2
Minus 65-mesh:								
Rougher concentrate*[2].....	23.2	38.5	21.7	16.6	12.4	2.3	52.4	1.2
Rougher middlings and coarse tailings..........	58.1	9.6					32.7	
Scavenger concentrate*..	8.7	33.6	19.8	14.0	17.6	7.2	17.1	1.2
Scavenger tailings......	49.4	5.4					15.6	
Rougher slime tailings....	16.9	11.1					11.0	
Composite or total......	100.0	17.1					100.0	
Calculated composite concentrate[1]...........	33.7	37.1	21.2	15.9	13.9	3.7	73.4	1.2

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.004; Pd <0.004; Au <0.0008; Ag 0.02.

NOTE.--Blank entry means data not available.

TABLE A-28. - Gravity table concentration of sample HB3M from Halibut Bay

Product[1]	wt pct	Analysis, pct Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2	Cr distribution, pct	Cr:Fe ratio
28- by 65-mesh concentrate*[2]	29.6	50.0	11.4	8.5	15.7	5.5	30.7	3.0
Minus 65-mesh:								
Rougher concentrate*[3].....	54.5	53.8	11.6	9.7	14.9	3.8	61.0	3.2
Rougher middlings and coarse tailings..........	7.4	21.8					3.3	
Scavenger concentrate*..	3.0	36.0	8.6	6.3	21.4	16.8	2.2	2.9
Scavenger tailings......	4.4	12.2					1.1	
Rougher slime tailings....	8.5	28.6					5.0	
Composite or total......	100.0	48.2					100.0	
Calculated composite concentrate[1]...........	87.1	51.9	11.4	9.2	15.4	4.8	93.9	3.1

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.002; Pd <0.002; Au <0.0004; Ag 0.01.
[3]Precious metals analysis, oz/ton: Pt <0.002; Pd <0.002; Au <0.0004; Ag <0.01.

NOTE.--Blank entry means data not available.

TABLE A-29. - Gravity table concentration of sample HB4M from Halibut Bay

Product[1]	wt pct	Analysis, pct Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2	Cr distribution, pct	Cr:Fe ratio
28- by 65-mesh concentrate*[2]	1.8	30.8	24.2	17.0	11.0	4.4	6.8	0.9
Minus 65-mesh:								
Rougher concentrate*[2].....	14.4	30.5	25.6	16.9	11.7	5.1	54.1	.8
Rougher middlings.........	9.1	12.5					13.9	
Scavenger concentrate*..	2.3	24.8	21.6	13.3	16.6	11.4	7.0	.8
Scavenger tailings......	6.8	8.3					6.9	
Rougher coarse tailings...	59.8	2.3					16.9	
Rougher slime tailings....	14.9	4.5					8.3	
Composite or total......	100.0	8.1					100.0	
Calculated composite concentrate[1]...........	18.5	29.8	25.0	16.5	12.2	5.8	67.9	.8

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.002; Pd <0.002; Au <0.0004; Ag 0.01.

NOTE.--Blank entry means data not available.

TABLE A-30. - Gravity table concentration of sample HB6M from Halibut Bay

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]	3.3	45.4	14.9	17.6	14.5	1.8	6.8	2.1
Minus 65-mesh:								
Rougher concentrate*[3].....	18.8	47.2	15.1	17.6	13.9	1.2	40.1	2.1
Rougher middlings.........	35.3	25.6					40.9	
Scavenger concentrate*..	5.7	47.7	12.9	9.8	20.5	6.9	12.3	2.5
Scavenger tailings......	29.6	21.3					28.6	
Rougher coarse tailings...	26.2	4.3					5.1	
Rougher slime tailings....	16.4	9.5					7.1	
Composite or total......	100.0	22.1					100.0	
Calculated composite concentrate[1]...........	27.8	47.1	14.6	16.0	15.3	2.4	59.2	2.2

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.004; Pd <0.004; Au <0.0008; Ag <0.01.
[3]Precious metals analysis, oz/ton: Pt <0.004; Pd <0.004; Au 0.0009; Ag 0.02.

NOTE.--Blank entry means data not available.

TABLE A-31. - Gravity table concentration of sample HB7M from Halibut Bay

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]	5.5	46.5	16.6	10.8	13.2	2.9	10.9	1.9
Minus 65-mesh:								
Rougher concentrate*[2].....	27.7	51.4	16.9	12.6	12.1	1.5	60.9	2.1
Rougher middlings.........	11.7	30.6					15.3	
Scavenger concentrate*..	5.8	49.0	16.1	10.9	13.9	3.3	12.1	2.1
Scavenger tailings......	5.9	12.5					3.2	
Rougher coarse tailings...	48.4	4.5					9.3	
Rougher slime tailings....	6.7	12.6					3.6	
Composite or total......	100.0	23.4					100.0	
Calculated composite concentrate[1]...........	39.0	50.4	16.7	12.1	12.5	2.0	83.9	2.1

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.002; Pd <0.002; Au <0.0004; Ag <0.01.

NOTE.--Blank entry means data not available.

TABLE A-32. - Gravity table concentration of sample HB8M from Halibut Bay

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]	11.8	46.2	13.1	14.4	17.3	3.4	14.6	2.4
Minus 65-mesh:								
Rougher concentrate*[3].....	45.0	47.4	13.4	15.2	15.9	2.2	57.0	2.4
Rougher middlings and coarse tailings..........	31.7	24.4					20.8	
Scavenger concentrate*..	12.5	45.0	12.7	13.7	17.6	4.5	15.1	2.4
Scavenger tailings......	19.2	11.0					5.7	
Rougher slime tailings....	11.5	24.6					7.6	
Composite or total......	100.0	37.3					100.0	
Calculated composite concentrate[1]...........	69.3	46.8	13.2	14.8	16.4	2.8	86.7	2.4

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.0006; Pd <0.0006; Au <0.0004; Ag <0.02.
[3]Precious metals analysis, oz/ton: Pt 0.001; Pd <0.0006; Au <0.0004; Ag <0.02.

NOTE.--Blank entry means data not available.

TABLE A-33. - Gravity table concentration of sample HB9M from Halibut Bay

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	4.6	54.5	12.4	11.5	17.6	2.7	5.8	3.0
Minus 65-mesh:								
Rougher concentrate*[3].......	50.3	54.9	12.5	11.6	17.0	2.4	63.4	3.0
Rougher middlings and coarse tailings..................	35.0	30.1					24.2	
Scavenger concentrate*....	13.7	54.6	11.6	11.4	17.7	2.2	17.2	3.2
Scavenger tailings........	21.3	14.3					7.0	
Rougher slime tailings......	10.1	28.6					6.6	
Composite or total........	100.0	43.5					100.0	
Calculated composite concentrate[1].............	68.6	54.8	12.3	11.6	17.2	2.4	86.4	3.0

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.004; Pd <0.004; Au <0.0008; Ag 0.01.
[3]Precious metals analysis, oz/ton: Pt <0.004; Pd <0.004; Au <0.0008; Ag <0.01.

NOTE.--Blank entry means data not available.

TABLE A-34. - Gravity table concentration of sample GL1M from Grant Lagoon

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	1.8	55.8	15.0	3.9	14.0	4.4	13.4	2.5
Minus 65-mesh:								
Rougher concentrate*[3].......	7.9	54.5	16.1	4.1	13.9	4.2	57.3	2.3
Rougher middlings...........	6.4	12.6					10.8	
Scavenger concentrate*....	1.3	43.7	15.8	3.3	18.9	9.7	7.6	1.9
Scavenger tailings........	5.1	4.7					3.2	
Rougher coarse tailings.....	67.2	1.1					9.8	
Rougher slime tailings......	16.7	3.9					8.7	
Composite or total........	100.0	7.5					100.0	
Calculated composite concentrate[1]............	11.0	53.4	15.9	4.0	14.5	4.9	78.3	2.3

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.002; Pd <0.002; Au 0.011; Ag 0.01.
[3]Precious metals analysis, oz/ton: Pt <0.002; Pd <0.002; Au <0.0004; Ag <0.01.

NOTE.--Blank entry means data not available.

TABLE A-35. - Gravity table concentration of sample MP1M from Miners Point

Product[1]	wt pct	Analysis, pct					Cr distribution, pct	Cr:Fe ratio
		Cr_2O_3	Fe	Al_2O_3	MgO	SiO_2		
28- by 65-mesh concentrate*[2]..	2.6	41.1	18.2	10.9	14.4	4.8	19.8	1.5
Minus 65-mesh:								
Rougher concentrate*[3].......	6.2	43.6	19.7	11.4	12.6	3.3	50.2	1.5
Rougher middlings...........	8.7	9.8					15.8	
Scavenger concentrate*....	1.6	34.1	18.0	9.1	17.0	9.6	10.1	1.3
Scavenger tailings........	7.1	4.3					5.7	
Rougher coarse tailings.....	66.6	.7					8.6	
Rougher slime tailings......	15.9	1.9					5.6	
Composite or total........	100.0	5.4					100.0	
Calculated composite concentrate[1]............	10.4	41.5	19.1	10.9	13.7	4.6	80.1	1.5

[1]Products with asterisks have been mathematically combined to give the calculated composite concentrate.
[2]Precious metals analysis, oz/ton: Pt <0.002; Pd <0.002; Au <0.0004; Ag 0.01.
[3]Precious metals analysis, oz/ton: Pt <0.002; Pd <0.002; Au 0.0023; Ag <0.01.

NOTE.--Blank entry means data not available.

APPENDIX B.--SAMPLE KEY

Location	Sample[1]	Field No.	Location	Sample[1]	Field No.
Tonsina area:			Kenai Peninsula--Con.		
Bernard Mountain...	BM1M	CM20488	Windy River........	WR1S[3]	CM17676
	BM2M	CM20495		WR2S[3]	CM17677
	BM3M	CM20496		WR3S[3]	CM17678
	BM4M	CM20497		WR4S[3]	([2])
	BM5M	CM20499			
	BM6M	CM18678	Claim Point........	CP1M	CM17679
	BM7M	CM20500		CP2M	CM17680
Sheep Hill...........	SH1M	CM20471	Kodiak Island:		
	SH2M	CM20472	Halibut Bay........	HB1M	CM18635
	SH3M	CM20466		HB2M	CM18636
	SH4M	CM20467		HB3M	CM19649
				HB4M	CM20268
Dust Mountain........	DM1M	CM20443		HB5M	CM17953
	DM2M	CM20445		HB6M	CM11168
	DM3M	CM20446		HB7M	CM19277
				HB8M	CM18623
Palmer area:				HB9M	CM18624
Wolverine Complex..	WC1M	CM19322			
			Grant Lagoon.......	GL1M	CM20261
Kenai Peninsula:					
Red Mountain.......	RM1M	([2])	Miners Point.......	MP1M	CM19461
	RM2M	CM17675			
	RM3M	CM17670A			
	RM4M	CM17670B			
	RM5M	([2])			
	RM6M	([2])			

[1]Prefix key: BM--Bernard Mountain; SH--Sheep Hill; DM--Dust Mountain; WC--Wolverine Complex; RM--Red Mountain; WR--Windy River; CP--Claim Point; HB--Halibut Bay; GL--Grant Lagoon; MP--Miners Point. Suffix key: M--Metallurgical test sample; S--screened alluvium sample.
[2]Composite sample provided by Anaconda Minerals Co.
[3]Placer sample.

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