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LABORATORY CONCENTRATION OF CHROMITE ORES, RED MOUNTAIN DISTRICT, KENAI PENINSULA, ALASKA

BY R. R. WELLS, F. T. STERLING, E. G. ERSPAMER, AND W. A. STICKNEY

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UNITED STATES DEPARTMENT OF THE INTERIOR
Fred A. Seaton, Secretary
BUREAU OF MINES
Marling J. Ankeny, Director

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by

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SUMMARY

As a part of the strategic minerals program of the Bureau of Mines, nine chromite-ore samples were obtained during the period 1949-56 from mines in the vicinity of Red Mountain, near Seldovia, Kenai Peninsula, Alaska. This report summarizes the results of beneficiation studies of the samples at the Bureau's Juneau, Alaska, and Albany, Oreg., laboratories.

In general, the ores were found amenable to concentration by gravity methods for producing concentrates that assayed over 48 percent chromic oxide. Intimate association of chromite and gangue minerals, however, necessitated fine grinding and limited the amount of chromite recoverable. Recovery of chromium in concentrate that assayed 48 percent chromic oxide or higher ranged from approximately 20 percent for low-grade ores (10 to 12 percent Cr_2O_3) to more than 95 percent for 1 high-grade sample (42 percent Cr_2O_3).

The iron content of the chrome-bearing mineral - hence, the chrome/iron ratio of finished concentrate - appears to vary with the grade of the ore. Concentrates made from high-grade ores had chrome/iron ratios as high as 3.1:1; the concentrates from low-grade ores, however, had chrome/iron ratios as low as 1.8:1.

INTRODUCTION

Almost all of the chromite consumed in the United States is obtained from foreign sources; world conditions or conditions within the supplying countries conceivably could interrupt the United States supply. Known domestic reserves of chromite are relatively small compared with requirements, and many are offgrade. In accordance with the Government's strategic minerals policy, the Bureau of Mines continues to search for additional domestic deposits and to determine the metallurgical characteristics of the ores.

Chromite deposits occur in a dunite intrusive in the vicinity of Red Mountain about 10 miles southeast of Seldovia, Kenai Peninsula, Alaska. The Federal Geological Survey briefly examined the area in 1910;[5/] further investigations during World War I and World War II resulted in complete mapping and the accumulation of

5/ Grant, U. S., and Higgins, B. F., Preliminary Report on the Mineral Resources of the Southern Part of the Kenai Peninsula: Geol. Survey Bull. 442, 1910, pp. 168-169.

considerable geologic data.[6 7 8 9] The Bureau of Mines explored the chromite deposits of the district in 1941 and 1942, and again during the summer of 1944.[10]

Approximately 30 chromite deposits of varying sizes and grades have been found in the area; those deposits covered by the Star Four, Chrome Queen, Juneau No. 1, and Juneau No. 2 claims were determined to contain significant quantities of ore. As a result of Geological Survey and Bureau of Mines exploratory work, two deposits have been developed and mined on a small scale. During World War II, 6,619 tons of ore averaging 42 percent chromic oxide was mined from the Chrome Queen deposit and delivered to the Metals Reserve Company stockpile at Jakalof Bay. Since 1954 approximately 15,000 tons of ore containing an average of approximately 46.0 percent chromic oxide has been mined from the Star Four deposit for delivery to the General Services Administration stockpile at Grants Pass, Oreg.

Neither the exploratory nor development work, however, included metallurgical testing of the ores. This paper purposes to supply supplementary information concerning the amenability to beneficiation treatment of Red Mountain chromite ores.

MARKETING SPECIFICATIONS

Chromite is marketed under three classifications: Low-silica, high-iron Chemical grade; high-alumina, low-iron Refractory grade; and high-chrome, low-iron Metallurgical grade.

For the manufacture of chromium chemicals, friable material containing a minimum of 44 percent chromic oxide and a maximum of 4 percent silica usually is specified. Either "lump ore" or concentrate is acceptable to most purchasers.

Purchasers of ore intended for manufacturing chromite refractories usually require lump ore, not more than 20 percent of which shall pass a Tyler Standard 10-mesh screen. The chemical requirements for such material usually specify a chromic oxide content of not less than 30 percent and a combined chromic oxide plus alumina content of at least 60 percent; material containing over 12 percent iron or over 5 to 7 percent silica seldom is acceptable.

Most purchasers of ore intended for manufacturing stainless steel and other metallurgical uses require a minimum chromic oxide content of 48.0 percent and a maximum sulfur and phosphorus content of 0.05 and 0.02 percent, respectively. A chrome/iron ratio (Cr/Fe) of 3.0:1 is requested, but material with ratios as low as 2.8:1 usually is accepted at a lower price. Allowable silica content depends, to some extent, upon the purchaser's requirements, but commonly 8 percent silica is the maximum permitted.

6/ Mertie, J. B., Jr., Chromite Deposits in Alaska: Geol. Survey Bull. 692, 1919, pp. 265-267.

7/ Gill, A. C., Chromite of Kenai Peninsula, Alaska: Geol. Survey Bull. 742, 1922, 52 pp.

8/ Guild, P. W., Chromite Deposits of Kenai Peninsula, Alaska: Geol. Survey Bull. 931-G, 1942, pp. 139-175.

9/ Gates, G. O., and Unkelsbay, A. B., Report on the Chromite Deposits of Red Mountain, Kenai Peninsula, Alaska: Geol. Survey unpublished report, 1942.

10/ Rutledge, F. A., Exploration of Red Mountain Chromite Deposits, Kenai Peninsula, Alaska: Bureau of Mines Rept. of Investigations 3885, 1946, 26 pp.

At present the United States Government is purchasing chromite ore and concentrates at incentive prices under the Minerals Stockpile Program. For domestic chromite delivered to Grants Pass, Oreg., the General Services Administration offers $115 per long dry ton of lump ore and $110 per long dry ton of fine ore or concentrate containing 48 percent chromic oxide and having a chrome/iron ratio of 3.0:1. A premium of $4.00 per ton is paid for each percentage point above 48 percent chromic oxide. A penalty of $3.00 per ton is charged for each 1 percent below 48 percent chromic oxide down to and including 42 percent. A penalty is also imposed for each 0.1 decrease in the chrome/iron ratio below 3.0:1 down to and including 2.0:1. A bonus is paid for each 0.1 increase in the chrome/iron ratio above 3.0:1 up to 3.5:1. The specifications require further that the silica content does not exceed 10 percent.

THE ORE

Physical Character

General

The chromite deposits of the Kenai Peninsula occur in masses of ultramafic rocks, chiefly dunite, which are intrusive into a complex series of graywackes, slates, cherts, limestones, and interbedded volcanic rocks. The dunite consists primarily of olivine, with small amounts of pyroxenite and serpentine with accessory chromite grains that constitute an estimated 1 percent of the rock; chrome-rich tabular and lenticular bodies are distributed irregularly throughout the dunite. The bands and lenses range in size from mere streaks to bodies 50 feet thick and several hundred feet long; their chromic oxide content ranges from 5 percent to nearly 50.

Chrome Queen Ore

Petrographic examinations of representative portions of the Chrome Queen samples revealed that essentially the ore is an altered peridotite containing chromite, olivine, and serpentine in varying proportions; some clinopyroxene and enstatite; relatively small amounts of quartz and feldspar; and very small amounts of limonite and magnetite. Traces of pyrite and chalcopyrite were detected in two samples.

The chromite is partly liberated in the minus-100-, plus-200-mesh fraction. A portion of the chromite, however, is disseminated through the olivine as inclusions 325-mesh or finer.

Juneau No. 1 Ore

Microscopic study of a portion of this ore showed that the sample essentially contains chromite and olivine; some serpentine and clinopyroxene; small amounts of chromium, chlorite (clinochlore), quartz, and feldspar; very small amounts of limonite and magnetite; and traces of pyrite and chalcopyrite.

The chromite is partly liberated in the minus-100-, plus-200-mesh fraction. Because of the fine-grained nature of the material, however, part of the chromite remains locked, even in the minus-300-mesh fraction.

Star Four Ore

These samples consist chiefly of olivine and chromite, some serpentine, relatively small amounts of associated amphibole and pyroxene, and very small amounts of magnetite and chromium-bearing chlorite. Also present is a trace amount of a fine-grained titanium mineral tentatively identified as anatase.

Most of the chromite is liberated in the fractions finer than 100-mesh. Because of intimate association of chromite and gangue, however, complete liberation is not attained, even in the minus-200-mesh fraction.

Chemical Character

Representative portions of each sample were analyzed chemically and spectrographically. Partial chemical analyses are listed in table 1. A semiquantitative spectrographic analysis revealed the presence and approximate quantities of the metals listed in table 2. Any other elements, if present, are in amounts lower than the minimum detectable by the routine technique employed.

TABLE 1. - Chemical analysis

Sample	Assay, percent								
	Cr_2O_3	Fe	SiO_2	Al_2O_3	MgO	Ni	S	P	V
CQ-1	42.6	10.5	11.0	7.7	13.1	0.25	1/0.01	1/0.05	1/0.05
CQ-2	35.9	9.7	16.9	5.3	27.7	.13	.04	1/ .05	1/ .05
CQ-3	33.3	9.5	16.0	5.3	27.2	.13	.04	1/ .05	1/ .05
CQ-4	42.4	9.9	11.0	6.7	25.1	.40	1/ .01	1/ .05	1/ .05
CQ-5	26.2	9.0	20.8	3.9	33.4	.30	1/ .01	1/ .05	1/ .05
CQ-6	12.5	8.3	30.3	2.0	40.3	.30	1/ .01	1/ .05	1/ .05
J-1	34.6	9.4	16.4	5.7	26.8	.14	.02	1/ .05	1/ .05
SF-1	33.9	10.1	16.7	6.6	27.2	.12	.03	1/ .05	1/ .05
SF-2	27.4	9.8	21.4	6.5	30.1	.10	.02	1/ .05	1/ .05
SF-3	10.4	9.0	30.9	5.3	37.6	.16	.03	1/ .05	1/ .05

1/ Less than.

TABLE 2. - Spectrographic analysis

Sample	Al	Ca	Co	Cr	Cu	Fe	Mg	Mn	Ni	Si	Ti	V
CQ-1	D	E	E	A	G	A	C	E	D	C	E	D
CQ-2	C	E	E	A	F	A	A	D	D	B	-	E
CQ-3	C-	E	E	A	F	A	A	D	D	B+	-	E
CQ-4	C	G	E	A	G	A	A	D	D	B	E	D
CQ-5	D	G	E	A	G	A	A	D	D	A	E	D
CQ-6	E	-	E	A	F	A	A	D	D	A	E	E
J-1	C	E	E	A	F	A	A	D	D	B+	-	E
SF-1	D	F	E	A	F	B	B	D	D	C	E	E
SF-2	D	F	E	A	F	B	A	D	D	B	E	D
SF-3	D-	-	-	B	G	A	A	D	D	B+	F	E

Legend: A - more than 10 percent
B - 5 to 10 percent
C - 1 to 5 percent
D - 0.1 to 1 percent
E - 0.01 to 0.1 percent
F - 0.001 to 0.01 percent
G - less than 0.001 percent
- - not detected

LABORATORY MINERAL DRESSING

Petrographic examinations of the ore samples and of the concentrate from preliminary tests showed that intimate association of chromite with silicate minerals precluded the possibility of producing concentrates by physical separation that would meet the specifications for Chemical-grade or Refractory-grade material. The investigation, therefore, was directed toward producing 48-percent-chromic oxide concentrate, with as high chrome/iron ratio as possible and with the other characteristics of Metallurgical-grade chromite.

Because the intimate chromite-gangue association prevented production of high-grade chromic oxide concentrate at coarse sizes, most of the testing was restricted to the investigation of tabling and flotation techniques. One sample (SF-1), however, was tested to determine the amenability of the ore to concentration by jigging for producing coarse concentrate that would meet the minimum stockpile purchasing specifications.

During the investigation much information was collected and compiled. For brevity, most of the data of secondary importance have been omitted from this paper. For example, concentration by high-intensity magnetic separation was tried on several of the samples but was generally unsatisfactory; therefore, results of only two magnetic-separation tests are included for direct comparison with other methods of concentration. Similarly, data from only one electrostatic separation test are shown. Comparative figures showing the effect of degree of grind have been minimized.

Concentration methods employed during the studies of Kenai chromite ores conformed with standard laboratory practice. Results of screen analyses of representative portions of each sample confirmed information obtained by microscopic examination and established that mineral locking precludes significant concentration by sizing.

Chrome Queen Sample 1

A 5-ton sample of ore reported to be representative of that produced from the Chrome Queen mine during 1942-44 was obtained by a Bureau of Mines engineer and submitted to the laboratory for beneficiation study.

Results of preliminary testing showed that this high-grade ore (42.6 percent Cr_2O_3) was amenable to concentration by tabling for the production of plus-48-percent-Cr_2O_3 concentrate, in spite of extremely intimate chromite-gangue association that precluded production of a low-grade reject. Additional table-concentration tests revealed that the most effective procedure consisted of roll-crushing ore to minus-35-mesh, hydraulically sizing, and treating on a laboratory diagonal-deck shaking table to produce concentrate, tailing, and slime. The tailing was reground to minus-65-mesh and re-treated to produce a second concentrate, a slime product, and a final tailing. This procedure recovered 72.4 percent of the chromium in a concentrate assaying 51.3 percent Cr_2O_3 and having a chrome/iron ratio of 3.05:1. Addition of the slime fractions increased the recovery to 82.5 percent; the resulting product assayed 47.5 percent Cr_2O_3 and had a chrome/iron ratio of 2.92:1 (table A-1).

Magnetic-separation treatment of sized fractions of ore, using a Wetherill-type separator, recovered 80.3 percent of the chromium in a concentrate that assayed 48.5 percent Cr_2O_3 and had a chrome/iron ratio of 2.91:1. No low-chromium tailing was made by this method, in spite of repeated cleanings. Operational difficulties were caused by adherence of fine material to the delivery belt of the separator (table A-2).

Electrostatic separation tests were conducted on this sample at the Eastern Experiment Station of the Bureau of Mines, College Park, Md. The electrostatic separator methods of conditioning are fully described in AIME Technical Publication 2408.[11] This treatment recovered 84 percent of the chromium at 46.9-percent-Cr_2O_3 grade. An additional cleaning step probably would yield a plus-48-percent Cr_2O_3 concentrate with a recovery of 75 to 80 percent of the chromium (table A-3).

Flotation tests were conducted in accordance with a method developed at the Salt Lake City laboratories of the Bureau of Mines.[12] The procedure consists of pulping deslimed sand with water to about 50 percent solids and adding an aqueous emulsion of oleic acid until flocculation is fairly complete. The pulp is diluted to about 25 percent solids, and dilute hydrofluoric acid is added until the flocs free themselves of gangue. The flocculated chromite floats rapidly, and additional collector is seldom required. The method was developed for flotation of unconsolidated beach sand; it is less applicable to treatment of consolidated ore because of loss of chromium in the slime formed during grinding.

Flotation of CQ-1 ore ground to minus-100-mesh and deslimed recovered 85.1 percent of the chromium at 49.5 percent Cr_2O_3 grade. Combination of the slime with the concentrate resulted in a product that contained 92.1 percent of the chromium and assayed 48.5 percent Cr_2O_3, the chrome/iron ratio was 2.91:1 (table A-4).

Several unsuccessful attempts were made to float silica from the Chrome Queen ore with cationic reagents.

A preliminary test indicated that tabling to produce a high-grade concentrate, followed by flotation of the table tailing, would give relatively low grade rejects and high recovery. A sample of ore was roll-crushed to minus-35-mesh, hydraulically sized, and tabled to produce a concentrate, slime, and tailing. The latter was ground to pass a 65-mesh sieve and retabled to produce a second concentrate, slime, and tailing. Chromite was floated from the table tailing in the usual manner. This treatment recovered 95.3 percent of the chromium in a combined concentrate and slime product that assayed 49.2 percent Cr_2O_3 and had a chrome/iron ratio of 2.96:1 (table A-5).

Chrome Queen Sample 2

This intermediate-grade sample (35.9 percent Cr_2O_3) was cut from the working face of the Chrome Queen adit by a Bureau of Mines engineer.

Ore samples were subjected to various degrees of grinding, hydraulically sized, and treated on a laboratory shaking table (tables A-6 to A-8). Table concentration of ore ground to minus-65-mesh and hydraulically sized recovered 74.4 percent of the total chromium in a product that assayed 48.2 percent Cr_2O_3 and had a chrome/iron ratio of 2.80:1. Small recoveries of plus-48-percent-Cr_2O_3 concentrate were obtained by treatment at coarser sizes.

11/ Fraas, Foster, and Ralston, O. C., The Electrostatic Separation of Several Industrial Minerals: AIME Tech. Publication 2408, 1948, 11 pp.

12/ Havens, Richard, Froth Flotation of Chromite With Fluoride: U. S. Patent 2, 412,217, Dec. 10, 1946.

Several tests were run involving tabling at relatively coarse sizes, with regrinding and retabling of the middling fraction. Best results were obtained by tabling ore ground to minus-35-mesh and hydraulically sized. The middling fraction was reground to minus-65-mesh and 150-mesh and retabled.

This treatment gave higher recovery than other tabling procedures but had the disadvantage of being rather complex. By this method 79.1 percent of the total chromium was recovered in a combined product that assayed 49.0 percent Cr_2O_3 and had a chrome/iron ratio of 2.89:1 (table A-9).

Fatty-acid flotation of chromite was not employed successfully on this ore. Best results were obtained by treating deslimed minus-100-mesh ore; 54 percent of the chrome was recovered at 54.4-percent-Cr_2O_3 grade. Inclusion of a cleaner tailing product lowered the grade of the combined product to 40.2 percent Cr_2O_3; total chromium recovery was 84.8 percent. A similar test recovered 81.4 percent of the chromium at 43.4-percent-Cr_2O_3 grade.

Chrome Queen Sample 3

The CQ-3 sample represented ore from the old stope of the Chrome Queen workings. This material was slightly coarser grained and of slightly lower grade (33.3 percent Cr_2O_3) than sample CQ-2 from the adit face.

Direct tabling of ore ground to minus-48-mesh recovered 79.5 percent of the total chromium in a concentrate that assayed 49.1 percent Cr_2O_3 and had a chrome/iron ratio of 2.75:1 (table A-10).

Tabling ore ground to minus-35-mesh, with regrinding and retreatment of middling, recovered 74.7 percent of the chromite in a product that assayed 51.7 percent Cr_2O_3 and had a chrome/iron ratio of 2.95:1. Inclusion of the regrind slime product increased the chromite recovery to 82.9 percent; the resulting combined product assayed 47.4 percent Cr_2O_3 (table A-11). A similar test produced a concentrate assaying 51.1 percent Cr_2O_3 and having a chrome/iron ratio of 2.9:1. Chromium recovery was 73.4 percent. Tabling of ore ground to minus-48-mesh, with re-treatment of middling ground to minus-150-mesh, recovered 74.6 percent of the chromium at 48.8 percent Cr_2O_3.

A sample of ore was crushed to minus-10-mesh and screen-sized to yield closely sized fractions. Each fraction was treated separately on a high-intensity Wetherill-type magnetic separator to produce a magnetic concentrate and tailing. Results were poor because lack of liberation in the coarser fractions resulted in low-grade concentrate and high tailing. In the finer size ranges the tailing was high due to mechanical inclusion of chromite in the reject.

By flotation, 65.9 percent of the total chromite was recovered in a rougher concentrate that assayed 45.8 percent Cr_2O_3. Cleaning raised the grade to 48.0 percent Cr_2O_3, with a chromium recovery of 52.7 percent.

Tests were run using flotation to scavenge chromite from table middling products. Although flotation concentrates assaying 40 to 45 percent Cr_2O_3 were made, the slight increase in overall recovery (approximately 2 percent) would not warrant inclusion of the flotation treatment.

Chrome Queen Sample 4

This sample (42.4 percent Cr_2O_3), reported to represent hand-sorted high-grade ore, was submitted to the laboratory by a representative of the Alaska Oil & Mineral Co.

A series of tests was made to determine the best grind for table concentration. Results were generally poor for ore stage-ground to minus-35-mesh; although some high-grade concentrate was made, recovery was low, and the tailing averaged 38 to 40 percent Cr_2O_3. A typical test showed a recovery of 32 percent of the total chrome at 53.0 percent Cr_2O_3 grade. Tabling ore ground to minus-48-mesh recovered 75.5 percent of the total chromium in a concentrate that assayed 52.9 percent Cr_2O_3 and had a chrome/iron ratio of 3.14:1. Addition of the grinding-slime product increased the recovery to 89.3 percent; the combined product assayed 48.0 percent Cr_2O_3 and had a chrome/iron ratio of 3.04:1 (table A-12). By tabling ore ground to minus-35-mesh, with regrinding and re-treatment of the primary table tailing, 70.9 percent of the total chromium was recovered in a combined concentrate that assayed 52.3 percent Cr_2O_3 and had a chrome/iron ratio of 3.11:1. The addition of various slime fractions permitted recoveries of 83.1 and 87.0 percent at grades of 48.0 and 46.9 percent Cr_2O_3, respectively (table A-13). In general, this method yielded results slightly inferior to those obtained by the simpler direct tabling of ore ground to minus-48-mesh.

Sample CQ-4 was not readily amenable to fatty-acid flotation. The best results obtained by this method recovered 69 percent of the total chromium in a concentrate that assayed 48.1 percent Cr_2O_3 and had a chrome/iron ratio of 3.00:1.

Of the several combined gravity-flotation techniques employed, the following procedure yielded the best results: Ore was stage-ground to minus-35-mesh and tabled to produce concentrate and tailing; the tailing was reground to minus-65-mesh and retabled; the minus-65-mesh tailing was treated by flotation to produce a scavenger concentrate and finished tailing. By this treatment, 78.7 percent of the total chromium was recovered in a combined concentrate that assayed 50.7 percent Cr_2O_3 and had a chrome/iron ratio of 3.07:1. Addition of various slime products increased the recoveries to 82.5 and 89.9 percent, with resulting grades of 49.2 and 46.4 percent Cr_2O_3, respectively (table A-14).

Chrome Queen Sample 5

This intermediate-grade sample (26.2 percent Cr_2O_3) was submitted by the Alaska Oil & Mineral Co. as material representative of Chrome Queen run-of-mine ore.

Samples of CQ-5 were subjected to various degrees of grinding, hydraulically sized, and treated on a laboratory shaking table. In all tests a large amount of chromite was retained in a middling fraction that was difficult to treat. Best results, obtained by grinding ore to minus-65-mesh before table treatment, recovered only 36 percent of the total chromium in a concentrate that assayed 49.7 percent Cr_2O_3 and had a chrome/iron ratio of 2.83. Twenty-five percent of the total chromium was contained in a middling product that assayed 37.6; repeated efforts to remove additional concentrate or tailing from this middling product were unsuccessful. Combination of the concentrate and middling resulted in an overall recovery of 61.0 percent at a grade of 43.9 percent Cr_2O_3 (table A-15). Similar treatment of ore ground to 48-mesh gave a recovery of only 23 percent of the chromium in a plus-48-percent Cr_2O_3 concentrate. Treatment of minus-100-mesh ore increased the loss of chromium as slime and did not appreciably reduce the amount of chromite contained in the middling fraction; approximately 35 percent of the chromium was recovered in a concentrate that assayed about 49 percent Cr_2O_3.

A series of tests was made in which ore was ground to relatively coarse size and tabled to produce concentrate, middling, tailing, and slime. The middling fraction was reground to a finer size and re-treated. Best results were obtained with a primary grind of minus-48-mesh with regrind of middling to minus-100-mesh before retreatment. This method recovered 45.3 percent of the total chromium in a product that assayed 49.1 percent Cr_2O_3 and had a chrome/iron ratio of 2.71:1. The final middling product contained 13.5 percent of the total chromium at a grade of 39.9 percent Cr_2O_3. Addition of the middling to the concentrate resulted in a product that assayed 46.6 percent Cr_2O_3 and contained 58.8 percent of the chromium in the ore (table A-16).

Fatty-acid flotation of chromite was not employed successfully on this ore. Best results were obtained by treatment of deslimed minus-100-mesh ore; less than 20 percent of the chromium was recovered at 48.2-percent-Cr_2O_3 grade.

Chrome Queen Sample 6

Sample CQ-6 (12.5 percent Cr_2O_3) was sorted reject from the Chrome Queen dump submitted to the laboratory by a representative of the Alaska Oil & Mineral Co.

Good recovery of chrome as plus-48-percent Cr_2O_3 was not made from this low-grade sample. Best results were obtained by tabling ore roll-crushed to minsu-48-mesh. This treatment recovered 32.2 percent of the total chromite in a concentrate that assayed 48.1 percent Cr_2O_3 and had a chrome/iron ratio of 2.22:1 (table A-17). Table concentration of ore crushed to minus-35-mesh recovered only 10 percent of the chromite at plus-48-percent-Cr_2O_3 grade. Grinding finer than 48-mesh resulted in additional loss of slime without significant reduction in tailing loss.

By tabling ore ground to minus-35-mesh, with re-treatment of middling ground to minus-65-mesh, 20.4 percent of the total chromite was recovered in a combined concentrate that assayed 47.6 percent Cr_2O_3 and had a chrome/iron ratio of 2.34:1 (table A-18).

In no test of this sample was a product made with a chrome/iron ratio greater than 2.5:1. The high iron content of the concentrate is attributed to the chemical structure of the chrome mineral. Pure chromite (Fe Cr_2O_4 or FeO Cr_2O_3) contains 68 percent chromium sesquioxide and 32 percent iron protoxide and has a chrome/iron ratio of 1.87:1. The iron, however, may be replaced by magnesium, and the chromium may be replaced by aluminum or ferric iron. The latter probably has occurred in this ore. Recent studies indicate that some chromites may show exsolution intergrowths with magnetite. In this instance the chromite may contain varying amounts of intimately associated magnetite which would be fine grained and not liberated even with the finest grinding. Whether or not the mechanical or chemical iron-inclusion theory is accepted, enough testing was conducted to show that mechanical concentration of the low-grade Chrome Queen ore will not yield a concentrate with a high chrome/iron ratio.

No encouraging results were obtained by flotation testing of this sample.

Juneau No. 1 Sample

This sample was obtained from trenches on the Juneau No. 1 claim; it is similar in grade (34.6 percent Cr_2O_3) and mineral content to the average ore of the deposit as determined by trenching and drilling exploration.

Results obtained by tabling ore ground to minus-35-mesh and minus-48-mesh were almost identical. The finer grind allowed production of lower grade tailing, but the advantage was offset by the production of additional slime. Typical results showed a recovery of 64.3 percent of the chromite in a concentrate that assayed 52.6 percent Cr_2O_3 and had a chrome/iron ratio of 2.94:1. Addition of a middling product increased the recovery to 84.7 percent; the combined product assayed 47.1 percent Cr_2O_3 and had a chrome/iron ratio of 2.82:1 (table A-19).

Tabling ore ground to minus-35-mesh, with regrinding and re-treatment of middling, recovered 70.7 percent of the total chromium in a concentrate that assayed 51.2 percent Cr_2O_3 and had a chrome/iron ratio of 2.92:1. Addition of the minus-150-mesh material without retabling resulted in recovery of 75.8 percent of the chromium at 47.9-percent-Cr_2O_3 grade.

Flotation techniques were not as effective as tabling for concentrating Juneau No. 1 ore. Best results obtained by flotation showed a recovery of 57.0 percent of the chromium at 47.0-percent-Cr_2O_3 grade. Likewise, flotation was unsatisfactory as a re-treatment method for table middlings.

Star Four Sample 1

This sample (33.9 percent Cr_2O_3) represented undersize reject from a one-half-inch slotted plate over which mine-run ore is passed for hand sorting and shipping. It was submitted to the laboratory by the Kenai Chrome Co. to determine its amenability to simple gravity concentration with hand-sorted oversize for direct shipment.

Although optimum liberation of chromite and gangue can be effected only in the minus-200-mesh size range, a portion of the material consists of relatively high-grade (plus-42-percent Cr_2O_3) particles.

The plus-10-mesh fraction of the sample was treated in a Harz-type jig; approximately 29 percent of the total chromite was recovered at a grade of 43.2 percent Cr_2O_3. Tabling the minus-10-mesh material without grinding recovered an equal amount of the chromite at 43.7-percent-Cr_2O_3 grade. The combined product assayed 43.4 percent Cr_2O_3 and contained 58.3 percent of the total chromite. Addition of a jig-middling product increased the recovery to 75.0 percent but decreased the grade to 41.2 percent Cr_2O_3 (table A-21).

The grade of the recovered product can be improved by grinding the ore before treatment. Jigging the minus-1/2-inch, plus-10-mesh fraction, with tabling of the undersize reground to pass 35-mesh, gave a 59.3-percent recovery of the total chromium in a combined concentrate that assayed 44.5 percent Cr_2O_3. Grinding all jig reject to minus-35-mesh and combining with the reground undersize before tabling resulted in recovery of 74.2 percent of the chromium at 44.5 percent Cr_2O_3.

Tabling ore ground to minus-48-mesh recovered 76.6 percent of the chromite in a concentrate assaying 48.0 percent Cr_2O_3 and having a chrome/iron ratio of 2.73:1 (table A-2). A similar test of ore ground to minus-65-mesh gave a recovery of 69.8 percent of the chromite at 48.2-percent-Cr_2O_3 grade; finer grinding effected an additional loss of slime without a significant decrease of loss in the sand tailing.

Tabling minus-35-mesh ore, with re-treatment of middling, recovered 64.8 percent of the chromite in a concentrate that assayed 49.5 percent Cr_2O_3 and had a chrome/iron ratio of 2.77:1. Addition of the regrind slime fraction increased the recovery to 80 percent; the combined product assayed 45.6 percent Cr_2O_3 (table A-23).

Results of flotation treatment of this sample were inferior to those obtained by tabling techniques. The best flotation test gave a recovery of 57.9 percent of the chromite at approximately 45 percent Cr_2O_3.

Star Four Sample 2

This sample (27.4 percent Cr_2O_3) is reported by the Kenai Chrome Co. to be representative of ore being mined at the Star Four property for treatment in a small concentrating plant that currently is being constructed.

A series of tabling tests run on ore stage-ground to minus-35-, 48-, 65-, and 100-mesh showed that best results could be obtained with a minus-65-mesh grind. This treatment recovered 66.9 percent of the total chromite in a concentrate that assayed 47.4 percent Cr_2O_3 and had a chrome/iron ratio of 2.44:1 (tables A-24 to A-27).

Tabling ore ground to minus-35-mesh, with re-treatment of middling reground to pass 65-mesh, recovered 61.7 percent of the chromite at a grade of 49.5 percent Cr_2O_3 (table A-28).

Results of several tests indicated that this ore is not amenable to direct flotation using the fatty-acid fluoride technique commonly employed for chromite flotation. Best results showed a recovery of 29 percent of the total chromite in a product that assayed 49.5 percent Cr_2O_3.

Several tests were run to determine the applicability of flotation for beneficiation of table middling. Best results, obtained by tabling ore ground to minus-100-mesh and flotation of the table middling reground to pass 200-mesh, recovered 50.6 percent of the chromite at 49.6-percent-Cr_2O_3 grade.

Star Four Sample 3

This low-grade material (10.4 percent Cr_2O_3) represents submarginal ore found at the edges of the ore bodies in the Star Four mine. Extremely intimate association of chromite and gangue limited the recovery of high-grade concentrate that could be made from this low-grade sample.

By tabling ore ground to minus-65-mesh, only 20.8 percent of the chromite was recovered in a concentrate that assayed 49.5 percent Cr_2O_3 and had a chrome/iron ratio of 1.77:1. Approximately 50 percent of the chromite was recovered at 42-percent-Cr_2O_3 grade. Nearly identical results were obtained by tabling ore ground to minus-48-mesh with two-stage re-treatment of middling at minus-100- and minus-200-mesh. These results were superior to those obtained by treatment of coarser or finer ore.

Tabling produced an extremely fine refractory middling that assayed about 20 percent Cr_2O_3 and contained 40 to 50 percent of the total chromite. Microscopic examination indicated that only a small part of this product consists of locked "true middling" grains. No method was found, however, to upgrade the material further.

Tabling and flotation treatment involved grinding ore to minus-48-mesh and tabling to produce concentrate, middling, and tailing; the middling was re-treated after grinding to pass 100-mesh; the middling of the second tabling stage was treated by flotation, using the standard oleic acid-hydrofluoric acid technique. By this method, 31.8 percent of the chromite was recovered in a combined concentrate that assayed 48.6 percent Cr_2O_3 and had a chrome/iron ratio of 1.75:1. The flotation reject products assayed over 19 percent Cr_2O_3 and contained 40.7 percent of the total chromite in the feed (table A-29).

Although concentrates were made by gravity and flotation techniques that assayed up to 51 percent Cr_2O_3, in no product did the chrome/ratio exceed 1.80:1. Petrographic studies of a number of table and panned concentrates revealed no discrete iron mineral, such as magnetite. The high iron content of the concentrate, therefore, is attributed to the chemical structure of the chrome mineral.

CONCLUSIONS

Each of the samples tested yielded concentrate that assayed at least 48 percent Cr_2O_3 with a maximum of 8 percent SiO_2. All concentrates contained less than 0.01 P and S. Chromium recovery ranged from 20 to 95 percent. The chrome/iron ratios of the concentrates varied widely; concentrate from one ore (SF-3) had a chrome/iron ratio below the 2.0:1 minimum acceptable under the Minerals Stockpile Program.

To compare the effectiveness of various treatment methods applied to the Red Mountain ores, results have been recalculated to show the recoveries obtainable at 48.0-percent-Cr_2O_3 grade. These summary data are shown in table 3.

A review of the data shown in table 3 shows that, for most of the samples treated, direct tabling of ore ground to minus-48- or minus 65-mesh yielded results as good or better than the more complicated procedure involving tabling and re-treatment of middling. Flotation was successful on only one high-grade sample from the Chrome Queen deposit.

A definite relationship appears to exist between the grade of ore treated and the recovery obtainable. A similar relationship exists between the sample grade and the average chrome/iron ratio of concentrates of 48.0-percent-Cr_2O_3 grade. These relationships are shown graphically in figures 1 and 2.

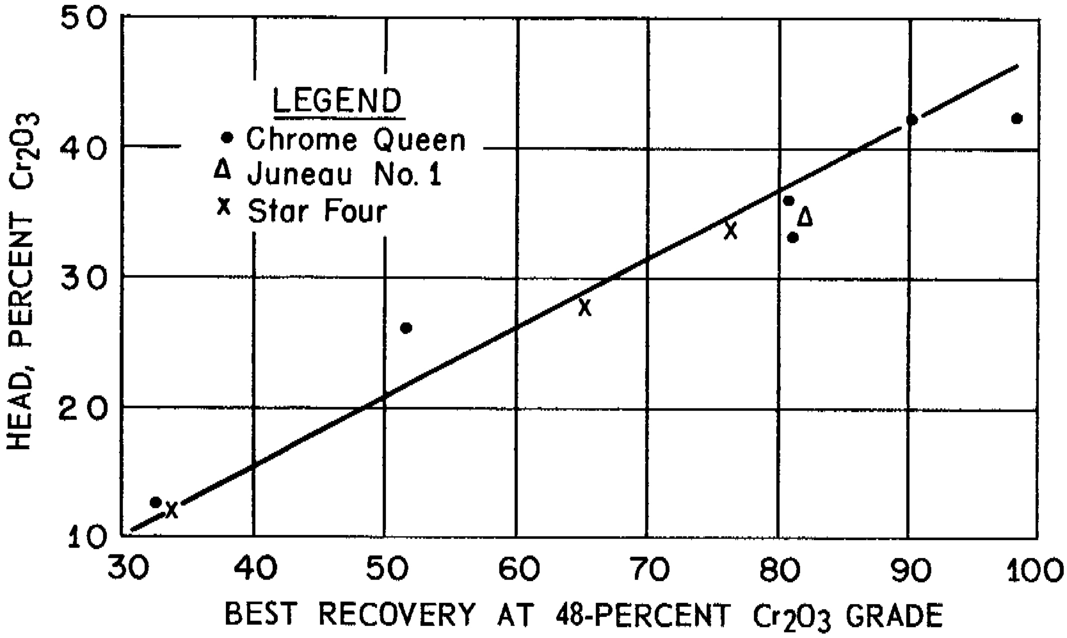

Figure 1. - Recovery vs. head grade.

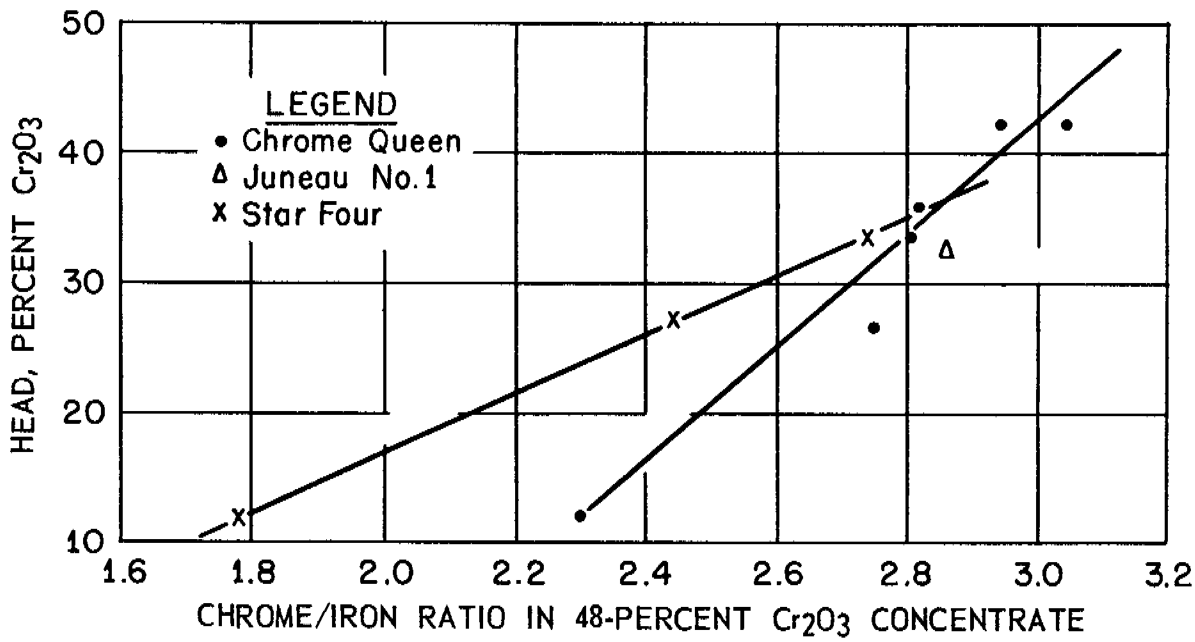

Figure 2. - Chrome/iron ratio vs. head grade.

TABLE 3. - Summary of results

Sample	Head assay, percent	Treatment	Recovery at 48.0 percent	Cr/Fe
CQ-1	42.6	Tabling, middling re-treatment	81.0	2.93
		Magnetic separation	81.6	2.90
		Electrostatic separation	77.0	3.01
		Flotation	94.0	2.91
		Tabling plus flotation	98.0	2.92
			Ave.	2.94
CQ-2	35.9	Tabling, minus-65-mesh	74.6	2.78
		Tabling, middling re-treatment	80.4	2.85
			Ave.	2.82
CQ-3	33.3	Tabling, minus-48-mesh	81.0	2.72
		Tabling, middling re-treatment	81.2	2.88
			Ave.	2.80
CQ-4	42.4	Tabling, minus-48-mesh	89.2	3.04
		Tabling, middling re-treatment	83.1	3.07
		Flotation	69.1	3.00
		Tabling plus flotation	85.5	3.04
			Ave.	3.04
CQ-5	26.2	Tabling, minus-65-mesh	43.5	2.79
		Tabling, middling re-treatment	51.5	2.69
			Ave.	2.74
CQ-6	12.5	Tabling, minus-48-mesh	32.3	2.22
		Tabling, middling re-treatment	23.0	2.37
			Ave.	2.30
J-1	34.6	Tabling, minus-48-mesh	81.6	2.84
		Tabling, middling re-treatment	75.5	2.88
			Ave.	2.86
SF-1	33.9	Tabling, minus-48-mesh	76.6	2.73
		Tabling, middling re-treatment	70.0	2.73
			Ave.	2.73
SF-2	27.4	Tabling, minus-65-mesh	65.0	2.43
		Tabling, middling re-treatment	65.0	2.44
			Ave.	2.44
SF-3	10.4	Tabling, minus-65-mesh	32.2	1.78
		Tabling and flotation	34.0	1.77
			Ave.	1.78

APPENDIX

TABLE A-1. - Chrome Queen sample 1; table concentration

Product	Weight, percent	Assay, percent Cr_2O_3	Fe	SiO_2	Distribution, percent Cr_2O_3	Cr/Fe
Concentrate 1	38.2	51.0	11.4	5.3	45.6	3.06
Concentrate 2	22.1	51.8	11.6	4.8	26.8	3.05
Primary slime	7.2	31.6	9.6	17.6	5.3	2.25
Secondary slime	6.8	30.3	9.8	16.8	4.8	2.11
Tailing	25.7	29.2	7.8	19.8	17.5	2.56
Calculated head	100.0	42.8	10.3	10.6	100.0	-
Combined conc.	60.3	51.3	11.5	5.1	72.4	3.05
Conc. plus slimes	74.3	47.5	11.1	7.4	82.5	2.92

TABLE A-2. - Chrome Queen sample 1; magnetic separation

Product	Weight, percent	Assay, percent Cr_2O_3	Fe	SiO_2	Distribution, percent Cr_2O_3	Cr/Fe
Magnetic conc.	72.2	48.5	11.4	5.9	80.3	2.91
Middling	3.5	40.0	-	-	3.2	-
Nonmagnetic tailing	24.3	29.5	-	-	16.5	-
Calculated head	100.0	43.6	-	-	100.0	-

TABLE A-3. - Chrome Queen sample 1; electrostatic separation

Product	Weight, percent	Assay, percent Cr_2O_3	Fe	SiO_2	Distribution, percent Cr_2O_3	Cr/Fe
Concentrate	77.6	46.9	10.8	7.7	84.0	2.97
Dust	10.6	35.2	-	-	9.4	-
Reject	11.8	24.0	-	-	6.6	-
Calculated head	100.0	43.3	-	-	100.0	-

TABLE A-4. - Chrome Queen sample 1; flotation of chromite

Metallurgical data

Product	Weight, percent	Assay, percent Cr_2O_3	Fe	SiO_2	Distribution, percent Cr_2O_3	Cr/Fe
Concentrate	75.1	49.5	11.6	6.6	85.1	2.92
Slime	7.8	39.0	9.8	15.1	7.0	2.72
Tailing	17.1	20.2	6.5	26.3	7.9	-
Calculated head	100.0	43.6	10.6	10.7	100.0	-
Conc. plus slime	82.9	48.5	11.4	7.5	92.1	2.91

Operating data

Grind: 100 percent minus-100-mesh

Circuit	pH	Reagents, pounds per ton: Oleic acid	Hydrofluoric acid
Condition	6.9	1.4	-
Rougher	3.6	-	0.4
Cleaner 1	3.5	.2	.2
Cleaner 2	3.5	-	.2
Total		1.6	.8

TABLE A-5. - Chrome Queen sample 1; combined tabling and flotation

Metallurgical data						
Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Table conc. 1	21.2	54.6	12.4	2.9	26.6	3.22
Table conc. 2	15.0	53.1	12.1	4.0	18.3	3.10
Flotation conc.	34.9	50.6	11.0	5.2	40.6	3.15
Primary slime	8.2	33.0	10.0	16.6	6.2	2.25
Secondary slime	4.9	31.7	9.6	17.6	3.6	2.25
Flotation tail	15.8	12.9	5.0	31.6	4.7	-
Calculated head	100.0	43.5	10.0	10.2	100.0	-
Combined conc.	71.1	52.3	11.7	4.2	85.5	3.05
Conc. plus slime	84.2	49.2	11.4	6.2	95.3	2.96

Operating data			
Grind: 100 percent minus-65-mesh			
Circuit	pH	Reagents, pounds per ton	
		Oleic acid	Hydrofluoric Acid
Condition	-	1.2	-
Rougher	4.0	-	0.45
Cleaner	3.8	.2	.20
Total		1.4	.65

TABLE A-6. - Chrome Queen sample 2; table concentration, minus-35-mesh

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate 1	23.07	54.3	12.2	3.3	35.9	3.05
Concentrate 2	16.65	43.8	10.5	10.4	20.9	2.86
Middling	17.56	37.3	9.7	15.1	18.8	2.63
Tailing	33.79	19.1	7.4	26.9	18.5	-
Slime	8.93	23.2	7.4	23.4	5.9	-
Calculated head	100.00	34.9	9.4	16.3	100.0	-
Combined conc.	39.72	49.9	11.5	6.3	56.8	2.97
Conc. and middling	57.28	46.0	10.9	9.0	75.6	2.89

TABLE A-7. - Chrome Queen sample 2; table concentration, minus-48-mesh

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate 1	12.37	52.6	12.5	4.3	18.3	2.88
Concentrate 2	34.41	47.1	11.8	7.8	45.8	2.73
Middling	7.70	32.3	9.5	19.2	7.0	2.33
Tailing	24.09	21.0	8.0	28.1	14.3	-
Slime	21.43	24.1	8.0	22.8	14.6	-
Calculated head	100.00	35.4	10.0	16.3	100.0	-
Combined conc.	46.78	48.6	12.0	6.9	64.1	2.78
Conc. and middling	54.48	46.3	11.6	8.6	71.1	2.73

TABLE A-8. - Chrome Queen sample 2; table concentration, minus-65-mesh

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate 1	13.59	54.7	13.0	3.1	20.7	2.88
Concentrate 2	41.94	46.0	11.4	8.0	53.7	2.76
Middling	17.22	24.0	8.0	26.0	11.5	-
Tailing	14.43	13.8	6.3	32.6	5.5	-
Slime	12.82	24.0	7.9	24.4	8.6	-
Calculated head	100.00	35.9	9.9	16.1	100.0	-
Combined conc.	55.53	48.2	12.0	6.8	74.4	2.80

TABLE A-9. - Chrome Queen sample 2; table concentration with middling re-treatment

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate	41.97	52.3	12.3	4.8	61.8	2.91
Middling	15.33	40.0	9.7	12.9	17.3	2.82
Tailing	30.63	15.2	6.5	29.1	13.1	-
Primary slime	1.76	20.4	6.8	22.1	1.0	-
Regrind slime	10.31	23.4	7.3	22.6	6.8	-
Calculated head	100.00	35.5	9.5	15.6	100.0	-
Combined conc. and middling..	57.30	49.0	11.6	7.0	79.1	2.89

TABLE A-10. - Chrome Queen sample 3; table concentration, minus-48-mesh

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate	17.19	55.4	12.7	2.4	28.6	2.98
Middling	36.75	46.1	12.0	8.8	50.9	2.63
Tailing	31.40	11.9	5.5	29.5	11.2	-
Slime	14.66	21.1	7.1	23.4	9.3	-
Calculated head	100.00	33.3	9.3	16.3	100.0	-
Conc. and middling	53.94	49.1	12.3	6.8	79.5	2.75

TABLE A.-11. - Chrome Queen sample 3; table concentration with middling re-treatment

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate	42.45	53.4	12.3	4.1	66.9	2.97
Middling (minus-150)	6.60	40.2	10.1	12.7	7.8	2.72
Tailing	32.26	13.2	5.6	28.5	12.6	-
Primary slime	8.45	18.1	6.4	24.3	4.5	-
Regrind slime	10.24	27.0	8.2	19.8	8.2	-
Calculated head	100.00	33.9	9.1	15.9	100.0	-
Conc. and middling	49.05	51.7	12.0	5.3	74.7	2.95
Conc., middling, and regrind slime	59.29	47.4	11.3	7.8	82.9	2.87

TABLE A-12. - Chrome Queen sample 4; table concentration, minus-48-mesh

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate	61.67	52.9	12.4	5.2	75.5	3.14
Tailing	19.65	23.6	7.3	24.1	10.7	-
Slime	18.68	31.9	8.6	18.0	13.8	-
Calculated head	100.00	43.2	10.1	11.3	100.0	-
Conc. plus slime	80.35	48.0	10.8	8.1	89.3	3.04

TABLE A-13. - Chrome Queen sample 4; table concentration with tailing re-treatment

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Primary concentrate	26.28	53.1	11.5	3.9	32.4	3.16
Regrind concentrate	32.15	51.6	11.5	6.1	38.5	3.07
Regrind tailing	20.05	28.0	7.3	20.9	13.0	-
Primary slime	5.29	31.7	7.4	18.4	3.9	-
Regrind slime	16.23	32.4	7.9	17.5	12.2	-
Calculated head	100.00	43.1	9.9	11.0	100.0	-
Combined concentrates	58.43	52.3	11.5	5.1	70.9	3.11
Conc. plus regrind slime	74.66	48.0	10.7	7.8	83.1	3.07
Conc. plus total slime	79.95	46.9	10.5	8.1	87.0	3.05

TABLE A-14. - Chrome Queen sample 4; combined tabling and flotation

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Combined table conc.	55.05	53.0	11.7	4.4	69.0	3.10
Flotation concentrate	10.60	38.8	9.0	14.6	9.7	2.94
Flotation tailing	17.96	23.7	6.3	23.9	10.1	-
Primary slime	5.33	30.3	7.9	16.9	3.8	-
Secondary slime	11.06	28.6	7.6	18.9	7.4	-
Calculated head	100.00	42.3	9.8	11.3	100.0	-
Combined conc.	65.65	50.7	11.3	6.0	78.7	3.07
Conc. plus primary slime	70.98	49.2	11.0	6.9	82.5	3.06
Conc. plus total slime	82.04	46.4	10.6	8.5	89.9	2.99

TABLE A-15. - Chrome Queen sample 5; table concentration, minus-65-mesh

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate	18.99	49.7	12.0	6.5	36.0	2.83
Middling	17.44	37.6	10.4	14.2	25.0	2.47
Tailing	40.36	15.2	7.4	29.0	23.4	-
Slime	23.21	17.7	7.9	27.0	15.6	-
Calculated head	100.00	26.2	8.9	21.7	100.0	-
Combined conc. and middling..	36.43	43.9	11.2	10.2	61.0	2.67

TABLE A-16. - Chrome Queen sample 5; table concentration with middling re-treatment

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Primary concentrate	4.88	53.6	13.5	0.6	9.9	2.72
Regrind concentrate	19.57	48.0	12.1	6.3	35.4	2.71
Middling	8.97	39.9	10.8	13.5	13.5	2.53
Primary tailing	27.97	12.8	6.9	31.6	13.5	-
Regrind tailing	19.85	18.7	7.8	27.6	14.0	-
Primary slime	14.12	16.8	7.1	27.0	8.9	-
Regrind slime	4.64	27.4	10.3	20.2	4.8	-
Calculated head	100.00	26.5	8.9	21.5	100.0	-
Combined conc.	24.45	49.1	12.4	5.2	45.3	2.71
Conc. plus middling	33.42	46.6	12.0	7.4	58.8	2.66

TABLE A-17. - Chrome Queen sample 6; table concentration, minus-48-mesh

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate	8.12	48.1	14.8	7.3	32.2	2.22
Tailing	77.10	9.2	8.8	33.0	58.4	-
Slime	14.78	7.7	8.2	33.3	9.4	-
Calculated head	100.00	12.1	9.2	31.0	100.0	-

TABLE A-18. - Chrome Queen sample 6; table concentration with middling re-treatment

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Minus-35-mesh concentrate ...	1.67	53.5	14.7	3.1	7.1	2.49
Minus-65-mesh concentrate ...	3.72	45.0	13.6	9.5	13.3	2.26
Minus-35-mesh tailing	46.06	5.6	7.5	35.5	20.5	-
Minus-65-mesh tailing	29.78	19.2	9.5	26.6	45.4	-
Slime	18.77	9.2	8.9	32.8	13.7	-
Calculated head	100.00	12.6	8.7	30.8	100.0	-
Combined conc.	5.39	47.6	13.9	7.5	20.4	2.34

TABLE A-19. - Juneau sample 1; table concentration, minus-48-mesh

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate 1	3.37	55.3	12.8	2.6	5.4	2.95
Concentrate 2	38.90	52.4	12.2	5.2	58.9	2.94
Middling	19.97	35.4	9.5	16.1	20.4	2.54
Tailing	21.21	14.9	6.1	29.3	9.1	-
Slime	16.55	13.0	5.9	30.1	6.2	-
Calculated head	100.00	34.6	9.3	16.5	100.0	-
Combined conc.	42.27	52.6	12.2	5.0	64.3	2.94
Conc. plus middling	62.24	47.1	11.4	8.6	84.7	2.82

TABLE A-20. - Juneau sample 1; table concentration with middling re-treatment

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
35/65-mesh concentrate	10.26	54.5	12.9	3.1	16.2	2.89
65/150-mesh concentrate	9.52	55.2	12.7	2.9	15.2	2.98
Minus-150-mesh concentrate ..	6.73	51.4	12.0	5.8	10.0	2.93
Minus-150-mesh middling	21.22	47.7	11.2	7.9	29.3	2.91
35/65-mesh tailing	7.07	10.1	5.4	33.2	2.1	-
65/150-mesh tailing	6.19	10.8	5.5	33.2	1.9	-
Minus-150-mesh tailing	6.95	25.4	7.6	23.2	5.1	2.29
Total slime	32.06	21.9	7.3	24.1	20.2	-
Calculated head	100.00	34.6	9.3	16.4	100.0	-
Combined conc. and middling..	47.73	51.2	12.0	5.5	70.7	2.92
Combined conc. and middling and minus-150-mesh tailing..	54.68	47.9	11.4	7.8	75.8	2.87

TABLE A-21. - Star Four sample 1; combined jig and table concentration

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Jig concentrate	22.05	43.2	11.8	10.0	29.1	2.51
Table concentrate	21.94	43.7	11.5	10.6	29.2	2.60
Jig middling	15.74	34.8	10.5	17.4	16.7	2.26
Jig tailing	21.51	20.1	8.0	26.0	13.2	-
Table tailing	17.73	20.6	7.7	25.4	11.2	-
Slime	1.03	18.5	6.8	26.2	.6	-
Calculated head	100.00	32.7	9.9	17.6	100.0	-
Combined conc.	43.99	43.4	11.7	10.3	58.3	2.53
Combined conc. and jig middling	59.73	41.2	11.4	12.2	75.0	2.47

TABLE A-22. - Star Four sample 1; table concentration, minus-48-mesh

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate	52.81	48.0	12.0	8.2	76.6	2.73
Tailing	32.24	13.7	6.8	31.5	13.3	-
Slime	14.95	22.4	9.0	25.7	10.1	-
Calculated head	100.00	33.1	9.9	18.3	100.0	-

TABLE A-23. - Star Four sample 1; table concentration with middling re-treatment

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate	42.73	49.5	12.2	6.5	64.8	2.77
Minus-35-mesh tailing	11.64	7.8	5.5	34.9	2.8	-
Minus-65-mesh tailing	12.76	15.0	6.6	30.2	5.9	-
Minus-150-mesh tailing	6.29	17.0	7.3	29.0	3.3	-
Primary slime	12.00	21.8	7.6	24.5	8.0	-
Regrind slime	14.58	34.2	10.2	16.4	15.2	2.29
Calculated head	100.00	32.6	9.5	17.9	100.0	-
Conc. plus regrind slime	57.31	45.6	11.7	9.0	80.0	2.67

TABLE A-24. - Star Four sample 2; table concentration, minus-35-mesh

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate	21.84	49.3	14.0	5.1	39.6	2.41
Middling	25.70	30.7	10.2	19.4	29.0	-
Tailing	31.88	14.9	7.1	31.4	17.5	-
Slime	20.58	18.3	8.1	28.0	13.9	-
Calculated head	100.00	27.2	9.6	21.9	100.0	-

TABLE A-25. - Star Four sample 2; table concentration, minus-48-mesh

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate	26.65	49.3	13.9	3.6	47.8	2.42
Middling	24.47	30.6	10.1	19.9	27.2	-
Tailing	33.21	11.9	6.4	34.6	14.3	-
Slime	15.67	18.8	8.1	28.0	10.7	-
Calculated head	100.00	27.5	9.6	21.7	100.0	-

TABLE A-26. - Star Four sample 2; table concentration, minus-65-mesh

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate	39.11	47.4	13.3	6.2	66.9	2.44
Middling	13.86	17.9	7.7	28.5	8.9	-
Tailing	26.28	9.6	5.9	34.9	9.1	-
Slime	20.75	20.2	8.2	26.9	15.1	-
Calculated head	100.00	27.8	9.5	21.1	100.0	-

Table A-27. - Star Four sample 2; table concentration, minus-100-mesh

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Concentrate	25.34	48.0	13.6	4.9	44.2	2.41
Middling	27.78	29.3	9.8	20.9	29.6	-
Tailing	22.41	9.3	5.7	35.8	7.6	-
Slime	24.47	20.9	8.3	25.7	18.6	-
Calculated head	100.00	27.5	9.5	21.3	100.0	-

TABLE A-28. - Star Four sample 2; table concentration with middling re-treatment

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Combined conc.	34.06	49.5	13.8	4.3	61.7	2.45
Minus-65-mesh middling	8.81	17.6	7.5	29.0	5.7	-
Minus-35-mesh tailing	24.26	14.2	6.9	31.5	12.6	-
Minus-65-mesh tailing	15.87	14.3	7.0	31.6	8.3	-
Primary slime	14.00	18.0	7.7	27.2	9.2	-
Secondary slime	3.00	22.2	9.0	24.5	2.5	-
Calculated head	100.00	27.3	9.5	21.3	100.0	-

TABLE A-29. - Star Four sample 3; combined tabling and flotation

Product	Weight, percent	Assay, percent			Distribution, percent Cr_2O_3	Cr/Fe
		Cr_2O_3	Fe	SiO_2		
Table concentrate	4.58	49.8	19.7	2.5	20.2	1.73
Flotation concentrate	2.80	46.7	17.9	4.4	11.6	1.79
Flotation cleaner tailing ...	7.58	19.3	11.2	24.9	13.0	-
Flotation rougher tailing ...	15.82	19.7	11.3	24.2	27.7	-
Table tailing	37.17	3.1	6.8	36.7	10.1	-
Primary slime	7.60	6.2	7.3	33.4	13.2	-
Secondary slime	24.45	6.1	7.3	33.4	4.2	-
Calculated head	100.00	11.2	8.9	30.3	100.0	-
Combined conc.	7.38	48.6	19.0	3.2	31.8	1.75

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