Bureau of Mines
Report of Investigations 5312

BENEFICIATION OF IRON-COPPER ORES FROM KASAAN PENINSULA, PRINCE OF WALES ISLAND, ALASKA

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

United States Department of the Interior — February 1957

BENEFICIATION OF IRON-COPPER ORES FROM KASAAN PENINSULA, PRINCE OF WALES ISLAND, ALASKA

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

* * * * * * * * * Report of Investigations 5312

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

February 1957

BENEFICIATION OF IRON-COPPER ORES FROM KASAAN PENINSULA, PRINCE OF WALES ISLAND, ALASKA

by

R. R. Wells,[1] E. G. Erspamer,[2] and F. T. Sterling[3]

CONTENTS

1/ Supervising metallurgist, Bureau of Mines, Region I, Juneau Alaska.
2/ Formerly metallurgist, Bureau of Mines, Region I, Juneau, Alaska.
3/ Extractive metallurgist, Bureau of Mines, Region I, Juneau, Alaska.

Report of Investigations 5312

ILLUSTRATIONS

TABLES

SUMMARY

This report summarizes the results of laboratory testing of copper-bearing magnetite ore from the Poorman, Rush & Brown, and Copper Center deposits, Kasaan Peninsula, Prince of Wales Island, southeastern Alaska. The ores contain minor amounts of chalcopyrite and pyrite. Intimate association of these sulfides with magnetite necessitates fine grinding for adequate liberation and rejection of copper and sulfur and for the production of high-grade iron concentrate low in objectionable impurities.

Laboratory tests indicated that the optimum results can be obtained by flotation of ore ground to minus-100-mesh, with subsequent wet magnetic separation treatment of the flotation tailing. A summary of results obtained by this treatment of the three samples tested is shown in table 1.

TABLE 1. - Summary of results

Ore	Head			Iron concentrate				Copper concentrate	
				Grade			Distb., percent	Grade	Distb., percent
	Assay, percent			Assay, percent				Assay, percent	
	Fe	Cu	S	Fe	Cu	S	Fe	Cu	Cu
Poorman	55.2	0.32	3.86	66.0	0.03	0.03	88.9	25.1	69.3
Rush & Brown..	54.6	1.10	2.32	68.2	.10	.9	88.9	24.6	70.6
Copper Center.	50.6	1.85	3.73	70.3	.04	.06	86.8	19.3	87.2

The three ores were amenable to flotation and magnetic separation treatment for the production of high-grade magnetite concentrate of low copper content. The method was effective for virtually complete removal of sulfur from the Poorman and Copper Center ores. The concentrate made from Rush & Brown ore contained 0.9 percent S; subsequent sintering, however, reduced the sulfur content to 0.15 percent. Total iron recovery ranged from 87 to 89 percent; this represents a recovery of approximately 99 percent of the magnetite present.

Cleaning of the flotation concentrates yielded copper products that assayed 19 to 25 percent Cu. Copper recovery ranged from 69 to 87 percent, depending upon the copper content of the various samples.

A similar method is in actual commercial use in eastern Pennsylvania, where ore from the Cornwall mine is crushed, concentrated and sintered profitably by the Bethlehem Steel Corp.

INTRODUCTION

Early in the century numerous deposits of copper ore were discovered on Kasaan Peninsula, Prince of Wales Island, Alaska (fig. 1); a smelting plant was built at Hadley, and shipments of ore were made from several mines. Deposits of magnetite were found to be associated closely with the copper ores but were not exploited. In 1915 Wright[4] reported:

> The only iron ore found in Kasaan Peninsula and the Copper Mountain area is magnetite which occurs in large bodies along contacts of diorites and limestones. No special study has been made of these deposits, which have been developed only in connection with the mining of the copper ores.... The utilization of these iron ores would seem to be a metallurgical problem, as there is no question that they occur in quantities that should make them commercially valuable.

In 1942 to 1944 the Bureau of Mines examined the more promising magnetite bodies by trenching, diamond drilling, and sampling.[5 6 7 8 9] Preliminary mineral-dressing studies were conducted on Poorman ore and on Mount Andrew ore. It was determined that the ores are similar; they consist of irregular contact metamorphic deposits of magnetite and quartz with minor amounts of chalcopyrite and pyrite. Because copper and sulfur are detrimental in iron and steel processing, the ores would require beneficiation treatment to fit them for blast-furnace use.

Although the known reserves of individual deposits are relatively small, the combined reserves within a limited area have been indicated to be substantial; therefore the purpose of this laboratory investigation was to develop a simple method of concentration that would be applicable to each of the deposits.

THE ORE

Samples

During a field investigation in the Kasaan Peninsula area (fig. 2), samples for metallurgical testing were obtained from the Poorman, Rush & Brown, and Copper

4/ Wright, Charles Will, Geology and Ore Deposits of Copper Mountain and Kasaan Peninsula, Alaska: Geol. Survey Prof. Paper 87, 1915, 110 pp.

5/ Wright, W. S., and Fosse, E. L., Exploration of the Jumbo Basin Iron Deposit, Prince of Wales Island, Southeastern Alaska: Bureau of Mines Rept. of Investigations 3952, 1946, 9 pp.

6/ Wright, W. S., and Tolonen, A. W., Mount Andrew Iron Deposit, Kasaan Peninsula, Prince of Wales Island, Southeastern Alaska: Bureau of Mines Rept. of Investigations 4129, 1947, 27 pp.

7/ Holt, S. P., and Sanford, Robert S., Poor Man Iron Deposit, Kasaan Peninsula, Prince of Wales Island, Southeastern Alaska: Bureau of Mines Report of Investigations 3956, 1946, 8 pp.

8/ Holt, S. P., Shepard, J. G., Thorne, R. L., Tolonen, A. W., and Fosse, E. L., Diamond Drilling at Rush & Brown Copper Mine, Kasaan Bay, Prince of Wales Island, Southeastern Alaska: Bureau of Mines Rept. of Investigations 4349, 1948, 7 pp.

9/ Erickson, Aner W., Investigation of Tolstoi Mountain Iron Deposits, Kasaan Peninsula, Prince of Wales Island, Southeastern Alaska: Bureau of Mines Rept. of Investigations 4373, 1948, 5 pp.

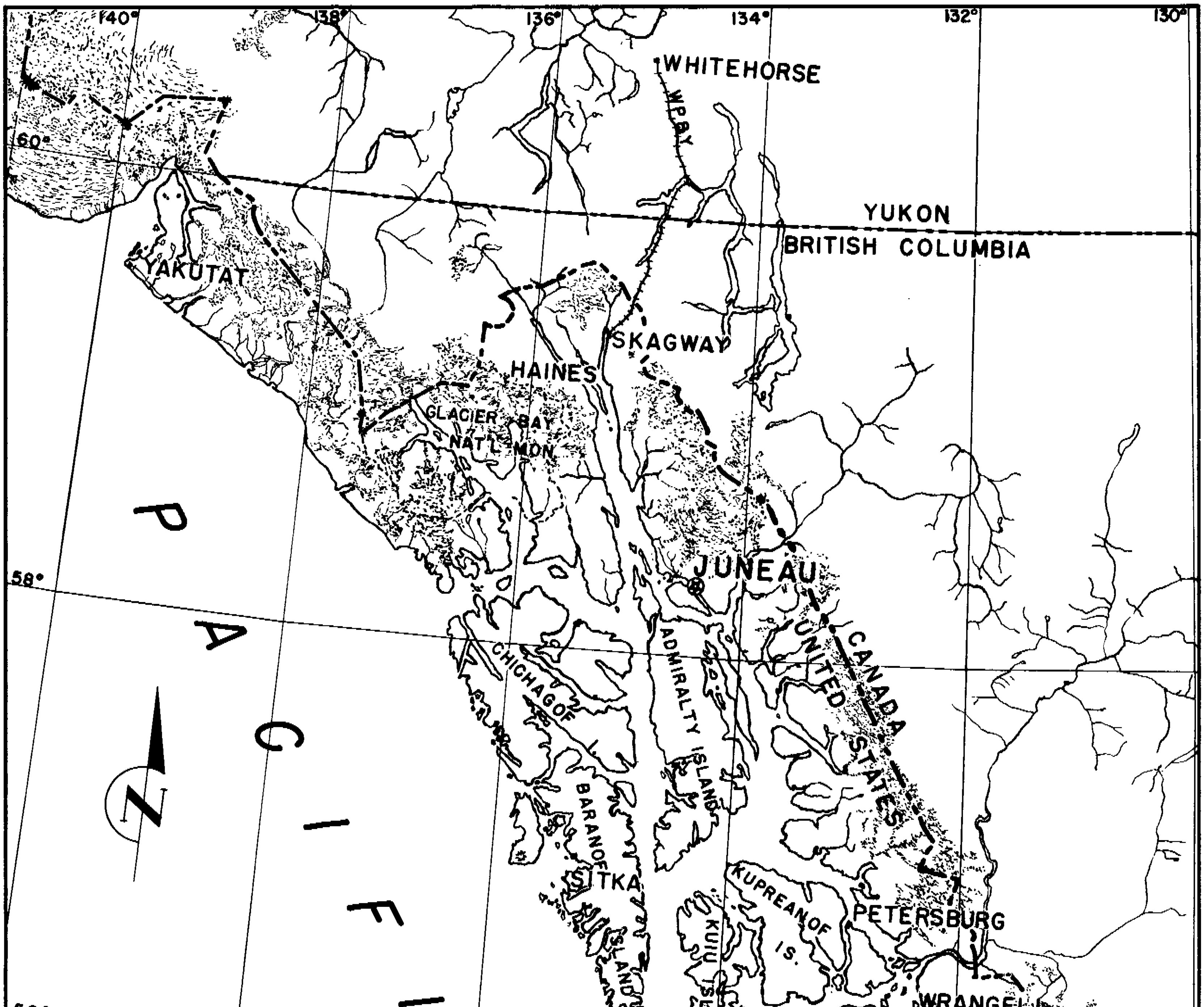

Figure 1. - Index map of southeastern Alaska. (Modified from map of Geological Survey.)

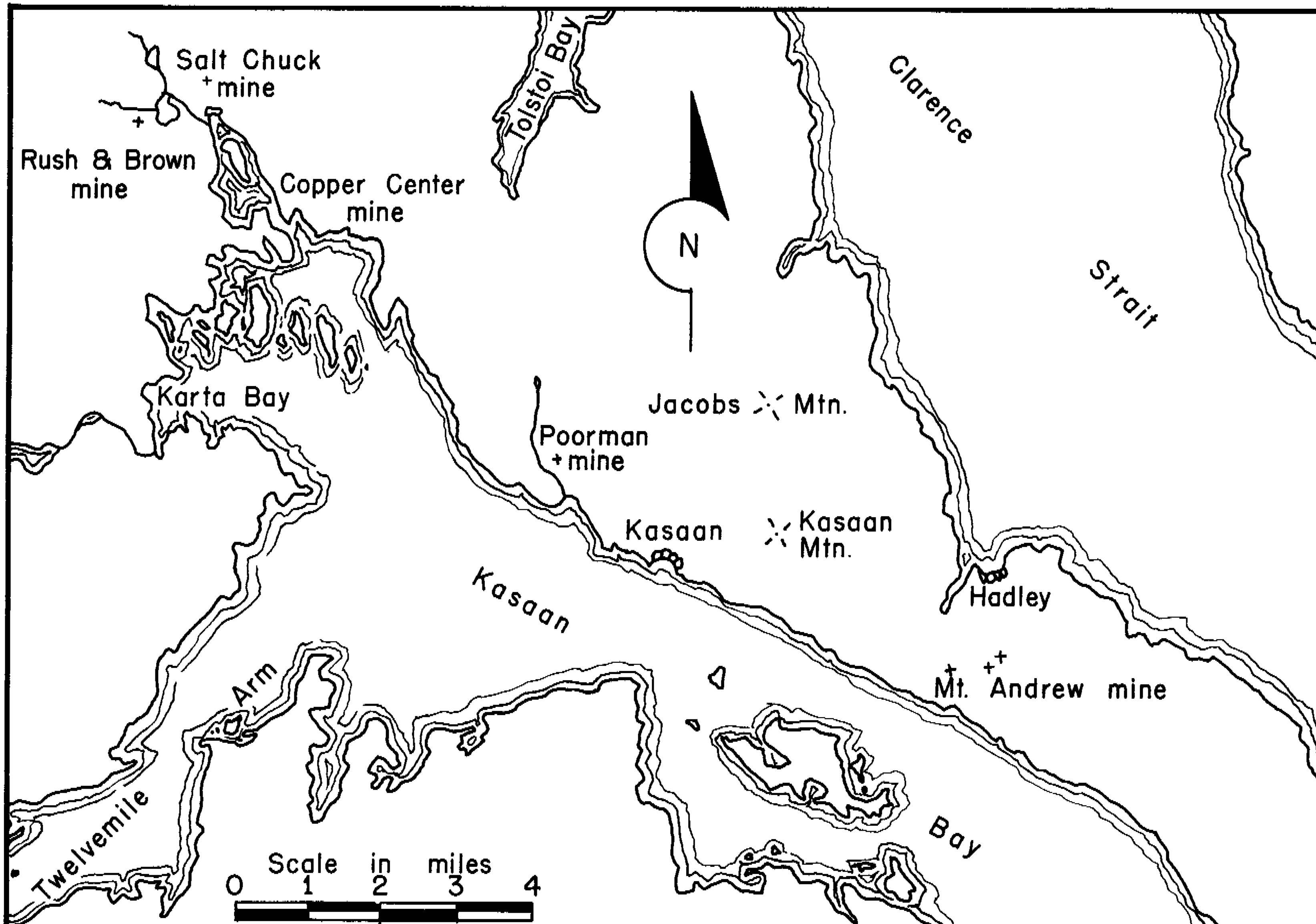

Figure 2. - Vicinity map, Kasaan Peninsula.

Center properties. A suite of samples was taken from old adits and trenches at the Poorman mine; the individual samples were assayed and blended to produce a composite which, as nearly as possible, was representative of the ore body as determined by previous field work.[10] The samples from the Rush & Brown and the Copper Center properties were, of necessity, procured from ore dumps near the portals of these mines. Consequently, the chemical analyses of these samples may be at variance with the average grade of the deposits. The samples tested, however, are believed to be representative of the ore of the Rush and Brown and the Copper Center mines in regard to physical and mineralogical nature.

Physical Character

Poorman Ore

The Poorman ore, as represented by the composite sample, contains magnetite with relatively small amounts of associated pyrite, chalcopyrite, calcite, altered amphibole and clinopyroxene, chlorite, quartz, altered feldspar, epidote, and limonite. Traces of malachite and apatite are also present.

The magnetite essentially is liberated in the minus-100-, plus-200-mesh fraction; however, a small amount of the fine-grained material remains locked with calcite and ferromagnesian minerals in the minus-200-mesh material. The chalcopyrite essentially is liberated in the minus-35-, plus-48-mesh size range.

Rush & Brown Ore

The sample of Rush & Brown ore submitted to the laboratory essentially contains magnetite, with some associated calcite, quartz, chalcopyrite, pyrite, chlorite, pyrrhotite, and limonite and small amounts of malachite and azurite.

Much of the chalcopyrite and malachite is liberated in the plus-200-mesh fraction. Because of the intimate association of the copper minerals with the other minerals of this sample, however, complete liberation does not take place, even in the minus-200-mesh.

Copper Center Ore

The sample of Copper Center ore essentially contains magnetite, with some associated quartz, chlorite, chalcopyrite, epidote, limonite, and small amounts of calcite, pyrite, malachite, amphibole, and azurite.

Much of the chalcopyrite, malachite, and azurite is liberated in the plus-200-mesh fraction. Complete liberation is not effected, however, even in the minus-200-mesh size range, because of intimate association of the copper minerals with magnetite and quartz.

Chemical Character

Chemical analyses of representative portions of the ores are shown in table 2.

10/ Work cited in footnote 7 (p. 2).

TABLE 2. - Chemical analyses

Ore	Assay, percent							Oz. per ton	
	Fe	Cu	S	P	CaO	MgO	SiO_2	Au	Ag
Poorman	55.2	0.32	3.86	0.03	3.2	1.3	9.7	0.02	0.03
Rush & Brown.	54.6	1.10	2.32	1/.01	4.0	.9	6.6	.01	Tr.
Copper Center	50.6	1.85	3.73	1/.01	2.6	.9	13.4	.05	.25

1/ Less than.

Semiquantitative spectrographic analyses indicated the presence and approximate amounts of the metals shown in table 3. Any other elements, if present, are in amounts less than the minimum detectable by the routine method used.

TABLE 3. - Spectrographic analyses

Ore	Al	As	Ca	Co	Cu	Fe	Mg	Mn	Mo	Na	Ni	Si	Ti	B
Poorman	D-	-	E	-	D-	A	F	E	-	-	F	D	E	F
Rush & Brown	C	-	C	F	C	A	C	D	E-	-	F	A	E	-
Copper Center	C	D	C	-	C	A	C-	D	-	D	F	A	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.

METHODS OF CONCENTRATION

Iron ore is a relatively low-priced commodity. Mineral-dressing treatment, therefore must be simple and inexpensive if the beneficiated product is to compete with direct-smelting ores. In addition, the beneficiated product must be made to conform to chemical and physical requirements for blast-furnace feed.

Inasmuch as smelting costs rise rapidly with the amount of slag-forming constituents in the ore, the ideal blast-furnace feed should be as high in iron and as low in silica content as possible. Both sulfur and phosphorus are deleterious, hence only minor amounts of these impurities are allowable. The presence of copper in significant quantities is considered undesirable. The physical condition of the feed is as important as its chemical composition. The product should be free of lumps greater than 6 inches in diameter and also should be free of fine material. Fine concentrate, therefore, requires sintering or nodulizing to meet physical specifications.

During this investigation, laboratory testing was directed toward production of a concentrate that contained at least 65 percent Fe, with a maximum of 0.10 percent each Cu and S. None of the ores tested contained appreciable amounts of phosphorus; consequently elimination of this element imposed no problem.

Because of the fine-grained nature of the ores, concentration testing was restricted to wet magnetic separation and flotation methods. Preliminary sintering tests were made on beneficiated products to determine the effectiveness of sintering for elimination of sulfur.

Direct Wet Magnetic Separation

To determine the degree of grinding necessary to effect rejection of copper and sulfur, samples of Poorman ore were ground to pass various screens ranging from 10- to 325-mesh. Each ground portion was treated in a low-intensity wet magnetic separator (Davis-tube type) to produce magnetic and nonmagnetic fractions. Similar treatment was given samples of Rush & Brown and Copper Center ores at sizes ranging from minus-20-mesh to minus-325-mesh. Results, showing iron, copper, silica, and sulfur contents, together with the distribution of these elements in each fraction, are summarized in tables 4, 5, and 6.

TABLE 4. - Wet magnetic separation, Poorman

Grind (mesh)	Product	Weight percent	Assay, percent				Distribution, percent			
			Fe	Cu	SiO_2	S	Fe	Cu	SiO_2	S
Minus-10	Magnetic	81.91	63.5	0.18	5.80	1.10	93.2	41.6	51.1	24.4
	Nonmag.	18.09	21.1	1.14	25.1	15.5	6.8	58.4	48.9	75.6
	Calc. head	100.00	55.8	.35	9.3	3.70	100.0	100.0	100.0	100.0
Minus-20	Magnetic	78.35	63.9	.14	5.72	1.04	93.0	30.9	48.8	21.2
	Nonmag.	21.65	17.5	1.12	21.7	14.0	7.0	69.1	51.2	78.8
	Calc. head	100.00	53.9	.35	9.2	3.85	100.0	100.0	100.0	100.0
Minus-35	Magnetic	76.87	64.8	.12	5.68	.68	92.1	27.4	45.0	14.8
	Nonmag.	23.13	18.5	1.10	23.1	13.0	7.9	72.6	55.0	85.2
	Calc. head	100.00	54.1	.35	9.7	3.53	100.0	100.0	100.0	100.0
Minus-48	Magnetic	75.86	65.6	.11	5.08	.51	91.3	23.5	40.9	11.0
	Nonmag.	24.14	19.7	1.12	23.1	13.0	8.7	76.5	59.1	89.0
	Calc. head	100.00	54.5	.35	9.4	3.52	100.0	100.0	100.0	100.0
Minus-65	Magnetic	74.91	67.2	.09	4.62	.25	91.0	19.3	38.0	5.1
	Nonmag.	25.09	19.8	1.12	22.5	13.9	9.0	80.7	62.0	94.9
	Calc. head	100.00	55.3	.35	9.1	3.68	100.0	100.0	100.0	100.0
Minus-100	Magnetic	73.32	67.2	.09	4.30	.05	91.0	18.8	32.5	1.1
	Nonmag.	26.68	18.3	1.07	24.6	12.0	9.0	81.2	67.5	98.9
	Calc. head	100.00	54.2	.35	9.7	3.24	100.0	100.0	100.0	100.0
Minus-150	Magnetic	73.28	68.6	.07	3.80	.04	90.6	14.7	30.7	0.8
	Nonmag.	26.72	19.6	1.11	23.5	13.1	9.4	85.3	69.3	99.2
	Calc. head	100.00	55.5	.35	9.1	3.53	100.0	100.0	100.0	100.0
Minus-200	Magnetic	73.19	68.6	.04	3.48	.02	90.3	8.2	28.7	.5
	Nonmag.	26.81	20.6	1.21	23.6	13.0	9.7	91.8	71.3	99.5
	Calc. head	100.00	55.6	.35	8.9	3.50	100.0	100.0	100.0	100.0
Minus-325	Magnetic	73.03	69.0	.03	3.24	1/ .01	89.6	6.5	25.2	.1
	Nonmag.	26.97	21.6	1.18	26.0	14.3	10.4	93.5	74.8	99.9
	Calc. head	100.00	56.2	.34	9.4	3.86	100.0	100.0	100.0	100.0

1/ Less than.

TABLE 5. - Wet magnetic separation, Rush & Brown

Grind (mesh)	Product	Weight, percent	Assay, percent				Distribution, percent			
			Fe	Cu	SiO_2	S	Fe	Cu	SiO_2	S
Minus-20	Magnetic	84.23	63.0	0.26	4.7	1.2	93.9	22.1	58.9	40.8
	Nonmag.	15.77	21.7	4.9	17.5	9.3	6.1	77.9	41.1	59.2
	Calc. head	100.00	56.5	1.00	6.7	2.48	100.0	100.0	100.0	100.0
Minus-35	Magnetic	82.21	64.0	.20	3.7	1.1	93.5	17.0	46.6	37.7
	Nonmag.	17.79	20.6	4.5	19.7	8.4	6.5	83.0	53.4	62.3
	Calc. head	100.00	56.3	.95	6.5	2.40	100.0	100.0	100.0	100.0
Minus-48	Magnetic	79.54	64.6	.14	3.3	.90	92.3	11.7	39.8	30.4
	Nonmag.	20.46	21.0	4.1	19.4	8.0	7.7	88.3	60.2	69.6
	Calc. head	100.0	55.7	.95	6.6	2.35	100.0	100.0	100.0	100.0
Minus-65	Magnetic	78.92	66.2	.10	3.0	.88	92.2	8.4	35.5	30.0
	Nonmag.	21.08	21.2	4.3	20.4	7.7	7.8	91.6	64.5	70.0
	Calc. head	100.00	56.7	.95	6.7	2.32	100.0	100.0	100.0	100.0
Minus-100	Magnetic	78.65	66.3	.08	2.9	.85	91.7	6.6	34.3	29.2
	Nonmag.	21.35	22.0	4.2	20.5	7.6	8.3	93.4	65.7	70.8
	Calc. head	100.00	56.8	.95	6.7	2.29	100.0	100.0	100.0	100.0
Minus-150	Magnetic	78.62	66.4	.08	2.4	.82	91.7	6.6	29.5	27.6
	Nonmag.	21.38	22.1	4.2	21.1	7.9	8.3	93.4	70.5	72.4
	Calc. head	100.00	56.9	.95	6.4	2.33	100.0	100.0	100.0	100.0
Minus-200	Magnetic	76.41	67.4	.08	2.3	.80	90.5	6.5	26.1	27.0
	Nonmag.	23.59	22.8	3.7	21.1	7.0	9.5	93.5	73.9	73.0
	Calc. head	100.00	56.9	.95	6.7	2.26	100.0	100.0	100.0	100.0
Minus-325	Magnetic	75.71	67.4	.06	2.2	.78	90.2	4.5	24.4	25.5
	Nonmag.	24.29	22.8	3.9	21.2	7.1	9.8	95.5	75.6	74.5
	Calc. head	100.00	56.6	1.00	6.8	2.32	100.0	100.0	100.0	100.0

TABLE 6. - Wet magnetic separation, Copper Center

Grind (mesh)	Product	Weight, percent	Assay, percent				Distribution, percent			
			Fe	Cu	SiO_2	S	Fe	Cu	SiO_2	S
Minus-20	Magnetic	69.75	65.3	0.21	3.0	0.57	88.6	7.6	15.7	10.3
	Nonmag.	30.25	19.3	5.9	34.5	11.4	11.4	92.4	84.3	89.7
	Calc. head	100.00	51.4	1.95	12.5	3.85	100.0	100.0	100.0	100.0
Minus-35	Magnetic	66.36	67.2	.18	2.3	.26	88.0	6.2	12.1	4.7
	Nonmag.	33.64	18.0	5.3	33.0	10.5	12.0	93.8	87.9	95.3
	Calc. head	100.00	50.6	1.90	12.6	3.71	100.0	100.0	100.0	100.0
Minus-48	Magnetic	65.95	67.7	.14	2.3	.18	87.6	5.0	11.7	3.2
	Nonmag.	34.05	18.6	5.1	33.7	10.6	12.4	95.0	88.3	96.8
	Calc. head	100.00	51.0	1.80	13.0	3.73	100.0	100.0	100.0	100.0
Minus-65	Magnetic	65.09	69.0	.14	2.2	.08	87.5	4.9	10.7	1.4
	Nonmag.	34.91	18.3	5.05	34.4	10.5	12.5	95.1	89.3	98.6
	Calc. head	100.00	51.3	1.85	13.4	3.72	100.0	100.0	100.0	100.0
Minus-100	Magnetic	63.92	69.2	.08	2.0	.06	87.3	2.8	9.6	1.0
	Nonmag.	36.08	17.8	4.95	33.2	10.2	12.7	97.2	90.4	99.0
	Calc. head	100.00	50.7	1.85	13.3	3.72	100.0	100.0	100.0	100.0
Minus-150	Magnetic	63.43	70.8	.04	1.5	.06	87.2	1.4	7.1	1.0
	Nonmag.	36.57	18.0	4.9	33.8	10.0	12.8	98.6	92.9	99.0
	Calc. head	100.00	51.5	1.80	13.3	3.70	100.0	100.0	100.0	100.0
Minus-200	Magnetic	63.00	70.9	.03	1.5	.06	86.8	1.0	7.3	1.0
	Nonmag.	37.00	18.4	5.0	32.3	9.9	13.2	99.0	92.7	99.0
	Calc. head	100.00	51.5	1.85	12.9	3.70	100.0	100.0	100.0	100.0
Minus-325	Magnetic	62.79	71.5	.03	1.3	.06	86.7	1.0	6.1	1.0
	Nonmag.	37.21	18.5	5.1	33.5	10.2	13.3	99.0	93.9	99.0
	Calc. head	100.00	51.8	1.90	13.3	3.85	100.0	100.0	100.0	100.0

The results of these series of tests showed that the Poorman, Rush & Brown, and Copper Center ores, as represented by the samples tested, are readily amenable to concentration by wet magnetic separation at relatively coarse sizes for the production of magnetite concentrates assaying more than 60 percent Fe. Intimate association of sulfides with the magnetite, however, necessitated grinding to approximately 100-mesh for adequate rejection of copper. Rejection of sulfur below the 0.10-percent limit was accomplished by treating minus-100-mesh Poorman and Copper Center ore samples. In the case of Rush & Brown ore, however, no test yielded low-sulfur concentrate; by treatment of ore ground to minus-325-mesh, sulfur content was reduced to 0.78 percent.

Two-Stage Magnetic Separation

To determine if a portion of the gangue could be rejected at relatively coarse size, a sample of Poorman ore was roll-crushed to minus-10-mesh and then treated in a wet magnetic separator. The magnetic fraction was reground to minus-100-mesh and retreated. Results are shown in table 7.

TABLE 7. - Two-stage magnetic separation, Poorman

Product	Weight, percent	Assay, percent			Distribution, percent		
		Fe	Cu	S	Fe	Cu	S
Minus-100-mesh mag....	74.51	67.2	0.09	0.10	89.7	19.2	2.0
Minus-100-mesh nonmag.	7.40	25.9	1.03	11.1	3.5	21.8	22.2
Minus-10-mesh nonmag..	18.09	21.1	1.14	15.5	6.8	59.0	75.8
Calc. head	100.00	55.8	.35	3.70	100.0	100.0	100.0
Combined nonmag.	25.49	22.5	1.11	14.2	10.3	80.8	98.0

Two-stage magnetic separation eliminated fine grinding of only 18 percent of the total ore. Recovery of iron was slightly inferior to that obtained by direct treatment of ore ground to minus-100-mesh. In addition, recovery of copper would necessitate fine grinding of the minus-10-mesh reject, thus nullifying any possible advantage of the two-stage treatment. This method of concentration was not investigated further.

Magnetic Separation Followed by Flotation

In an effort to produce separate marketable concentrates of iron and copper, the reject from magnetic separation was treated by flotation in a series of tests. Best results were obtained from ore ground to minus-100-mesh. The fine ore was magnetically separated in a Davis-tube type separator to recover magnetite; the nonmagnetic fraction was treated by flotation to recover chalcopyrite. Results obtained by this treatment of each of the three ores are shown in tables 8, 9, and 10.

TABLE 8. - Magnetic separation followed by flotation, Poorman

Metallurgical data

Product	Weight, percent	Assay, percent				Distribution, percent			
		Fe	Cu	SiO_2	S	Fe	Cu	SiO_2	S
Magnetic	75.29	66.0	0.10	4.9	0.2	90.8	23.5	33.9	4.4
Cleaner concentrate.	1.75	39.4	10.1	2.2	43.0	1.3	55.5	-	22.1
Cleaner tailing	5.64	39.9	.69	7.6	41.0	4.1	12.2	3.9	67.9
Rougher tailing	17.32	12.0	.16	39.1	1.1	3.8	8.8	62.2	5.6
Calculated head	100.00	54.7	.32	10.9	3.4	100.0	100.0	100.0	100.0

Operation data

Grind: Minus-100-mesh

Circuit	Time, minutes	pH	Reagents, pound per ton			
			CaO	NaCN	Z-3[1]	D-250[2]
Cu rougher	5	10.6	0.3	0.1	0.2	0.04
Cu cleaner	3	10.0	-	-	-	-

1/ Potassium ethyl xanthate.
2/ Dowfroth 250, frother.

TABLE 9. - Magnetic separation and flotation, Rush & Brown

Metallurgical data

Product	Weight, percent	Assay, percent				Distribution, percent			
		Fe	Cu	SiO_2	S	Fe	Cu	SiO_2	S
Magnetic	77.27	67.0	0.20	2.3	0.95	91.4	14.8	28.2	31.1
Cu cl. conc..	3.87	36.7	19.0	2.8	36.3	2.5	70.4	1.7	59.5
Cu cl. tail..	1.09	29.8	4.4	17.6	9.8	.6	4.6	3.0	4.5
Ro tail......	17.77	17.5	.33	23.8	.65	5.5	10.2	67.1	4.9
Calc. head...	100.00	56.6	1.05	6.3	2.36	100.0	100.0	100.0	100.0

Operation data

Grind: Minus-100-mesh

Circuit	Time, minutes	pH	Reagents, pounds per ton of feed				
			Na_2CO_3	Z-6 1/	D-250 2/	R-301 3/	Met 4/
Condition	5	-	5.0	0.5	0.04	-	-
Rougher	4	9.7	-	-	.1	1.0	1.0
Cleaner	3	8.5	-	-	.1	-	-

1/ Potassium pentasol xanthate.
2/ Dowfroth 250, frother.
3/ American Cyanamid Reagent 301.
4/ Sodium metasilicate.

TABLE 10. - Magnetic separation and flotation, Copper Center

Metallurgical data

Product	Weight, percent	Assay, percent				Distribution, percent			
		Fe	Cu	SiO_2	S	Fe	Cu	SiO_2	S
Magnetic.....	67.61	69.2	0.08	2.1	0.06	88.6	3.0	10.9	1.2
Cu cl. conc..	6.20	35.2	23.5	.8	37.9	4.1	81.9	.4	66.0
Cu cl. tail..	2.34	38.0	4.9	8.1	37.2	1.7	6.5	1.4	24.4
Ro tail......	23.84	12.5	.64	47.8	1.1	5.6	8.6	87.3	7.4
Calc. head...	100.00	52.8	1.80	13.1	3.55	100.0	100.0	100.0	100.0

Operation data

Grind: Minus-100-mesh

Circuit	Time, minutes	pH	Reagents, pounds per ton of feed			
			Na_2CO_3	Z-6 1/	D-250 2/	CaO
Condition	5	-	5.0	0.5	0.4	-
Rougher	3	9.1	-	-	-	-
Cleaner	2	9.8	-	-	-	0.1

1/ Potassium ethyl xanthate.
2/ Dowfroth 250, frother.

Magnetic separation of minus-100-mesh Poorman ore recovered 90.8 percent of the total iron in a concentrate that assayed 66.0 percent Fe, 0.10 percent Cu, 4.9 percent SiO_2, and 0.2 percent S. The sulfur rejection was inferior to that obtained in the corresponding test of a smaller sample (see table 4), probably due to overfeeding of the small separator during this test. Flotation of the nonmagnetic portion of the Poorman ore resulted in recovery of 55.5 percent of the copper at 10.1-percent-Cu grade.

Similar treatment of Rush & Brown ore recovered 91.4 percent of the iron in a concentrate that contained 67.0 percent Fe, 0.20 percent Cu, 2.3 percent SiO_2, and

0.95 percent S. The copper flotation concentrate assayed 19.0 percent Cu; copper recovery was 70.4 percent.

Magnetic separation treatment of the Copper Center ore resulted in a concentrate assaying 69.2 percent Fe, 0.08 percent Cu, 2.1 percent SiO_2, and 0.06 percent S; the concentrate contained 88.6 percent of the total iron. Flotation of the nonmagnetic portion of the ore recovered 81.9 percent of the copper at 23.5 percent Cu grade.

In general, copper and sulfur content of the iron concentrate was high in all tests. This is attributed to the collection of locked magnetite-sulfide particles in the iron product.

Flotation Followed by Magnetic Separation

In an effort to make a cleaner iron product by elimination of the locked magnetite-sulfide particles, a reverse treatment method was tried. Ore was ground to minus-100-mesh; the sulfides were removed by flotation and cleaned to produce a copper concentrate; the flotation tailing was magnetically separated to produce a magnetite concentrate. Results are shown in tables 11, 12, and 13.

TABLE 11. - Flotation followed by magnetic separation, Poorman

Metallurgical data

Product	Weight, percent	Assay, percent				Distribution, percent			
		Fe	Cu	SiO_2	S	Fe	Cu	SiO_2	S
Copper concentrate ..	0.88	35.3	25.1	1.9	38.7	0.6	69.3	0.2	10.1
Cleaner tail nonmag..	6.58	41.2	.69	7.4	42.4	5.0	14.1	4.9	82.4
Cleaner tail mag. ...	1.36	61.0	.83	5.4	6.9	1.5	3.4	.7	2.8
Rougher tail nonmag..	18.36	11.9	.11	33.7	.75	4.0	6.3	62.5	4.1
Rougher tail mag. ...	72.88	66.0	.03	4.3	.03	88.9	6.9	31.7	.6
Calculated head	100.00	54.1	.32	9.9	3.39	100.0	100.0	100.0	100.0
Combined mag.	74.18	65.9	.04	4.3	.16	90.4	10.3	32.4	3.4

Operation data

Grind: Minus-100-mesh

Circuit	Time, minutes	pH	Reagents, pounds per ton			
			CaO	NaCN	Z-3[1]	D-250[2]
Cu rougher	2.5	11.3	1.9	0.1	0.2	0.04
Cu cleaner	5	10.8	-	.05	.1	.04

1/ Potassium ethyl xanthate.
2/ Dowfroth 250, frother.

TABLE 12. - Flotation and magnetic separation, Rush & Brown

Metallurgical data

Product	Weight, percent	Assay, percent				Distribution, percent			
		Fe	Cu	SiO_2	S	Fe	Cu	SiO_2	S
Cu cl conc.	2.70	34.9	24.6	3.2	29.6	1.6	70.6	1.3	36.2
Cl tail mag. ...	2.65	63.2	0.75	2.2	2.2	2.1	1.5	.7	1.9
Cl tail nonmag..	1.89	35.6	6.2	7.9	20.1	1.7	17.4	3.3	24.1
Ro tail mag. ...	74.53	68.2	.10	2.8	0.9	88.9	8.0	25.5	30.4
Ro tail nonmag..	18.23	17.9	.13	24.4	.9	5.7	2.5	69.2	7.4
Calc. head	100.00	57.2	.95	6.9	2.21	100.0	100.0	100.0	100.0
Combined mag. ..	76.42	68.1	.12	2.8	.93	91.0	9.5	28.8	32.3

TABLE 12. - Flotation and magnetic separation, Rush & Brown (Con.)

Operation data

Grind: Mesh-100-mesh

Circuit	Time, minutes	pH	Reagents, pounds per ton of feed			
			Na_2CO_3	Z-6 1/	D-250 2/	NaCN
Condition	5	-	2.0	0.3	0.08	-
Rougher	2	9.5	-	-	-	-
Cleaner	1.5	8.0	-	-	-	0.3

1/ Potassium pentasol xanthate.
2/ Dowfroth 250, frother.

TABLE 13. - Flotation and magnetic separation, Copper Center

Metallurgical data

Product	Weight, percent	Assay, percent				Distribution, percent			
		Fe	Cu	SiO_2	S	Fe	Cu	SiO_2	S
Cu cl conc.	7.97	37.7	19.3	0.05	36.4	5.7	87.2	-	77.0
Cu cl tail nonmag.	1.67	31.4	4.35	16.0	42.0	1.0	4.1	2.2	18.6
Cu cl tail mag.	.73	66.4	.70	2.6	.9	.9	.3	.2	.2
Ro tail mag.	65.48	70.3	.04	1.8	.06	86.8	1.5	9.6	1.0
Ro tail nonmag.	24.15	12.3	.50	44.8	.5	5.6	6.9	88.0	3.2
Calc. head	100.00	53.0	1.75	12.3	3.75	100.0	100.0	100.0	100.0
Combined magnetic	66.21	70.2	.05	1.8	.07	87.7	1.8	9.8	1.2

Operation data

Grind: Minus-100-mesh

Circuit	Time, minutes	pH	Reagents, pounds per ton of feed		
			Na_2CO_3	Z-6 1/	D-250 2/
Condition	4	-	2.0	0.3	0.08
Rougher	2	9.0	-	-	-
Cleaner	2	8.5	-	-	-

1/ Potassium ethyl xanthate.
2/ Dowfroth 250, frother.

Flotation of Poorman ore, followed by magnetic separation of flotation tailing, recovered 90.4 percent of the total iron in a concentrate that assayed 65.9 percent Fe, 0.04 percent Cu, 0.16 percent S, and 4.3 percent SiO_2. The cleaned copper concentrate contained 69.3 percent of the copper at 25.1-percent Cu grade.

By direct flotation of minus-100-mesh Rush & Brown ore, 70.6 percent of the copper was recovered at 24.6-percent-Cu grade. Magnetic separation of the flotation rougher tailing recovered 88.9 percent of the iron in a concentrate that assayed 68.2 percent Fe, 0.10 percent Cu, 0.9 percent S, and 2.8 percent SiO_2. An additional 2.1 percent of the iron can be recovered by magnetic separation of the cleaner tailing; the combined product would assay 68.1 percent Fe, 0.12 percent Cu, 0.93 percent S, and 2.8 percent SiO_2.

By flotation, 87.2 percent of the copper in Copper Center ore was recovered in a concentrate that assayed 19.3 percent Cu. Magnetic separation of the combined flotation tailings recovered 87.7 percent of the iron in a concentrate that assayed 70.2 percent Fe, 0.05 percent Cu, 1.8 percent SiO_2, and 0.07 percent S.

In general, flotation followed by magnetic separation effected more complete rejection of impurities from the iron concentrate than the reverse procedure. This treatment is similar to that developed at the Rolla, Missouri laboratory of the Bureau of Mines for the treatment of Mount Andrew ore.11/ The Mount Andrew ore, however, responded to flotation after grinding to minus-35-mesh. Preliminary flotation tests of Poorman, Rush & Brown, and Copper Center ores indicated that grinding to at least minus-65-mesh is required to produce a tailing low in copper and sulfur.

As the bulk of the total ore would require regrinding to minus-100-mesh for magnetic separation, it was decided that a simple 1-circuit grinding of all of the ore to minus-100-mesh would be preferable to a treatment involving primary grinding to minus-65-mesh, flotation, and regrinding of the flotation tailing.

Sintering

Preliminary sintering tests were run on concentrates made from the Kasaan Peninsula ores, using a laboratory sintering machine to simulate plant practice. Although exhaustive tests were not made, the sinters produced appeared to be similar in fuel requirements, moisture requirements, physical strength, and reducibility to those made from other magnetite concentrates.

The sintering operation alters slightly the chemical composition of the concentrate. The iron percentage is reduced slightly because of conversion of some magnetite to hematite and because of a minor amount of dilution of ash from the added coke. Most of the sulfur is burned off.

Typical results obtained from sintering iron concentrate of the Kasaan Peninsula ores are shown in table 14.

TABLE 14. - Sintering results

	Concentrate				Sinter					
	Assay, percent				Assay, percent					
	Fe	Cu	S	SiO_2	Fe	Cu	S	SiO_2	P	TiO_2
Poorman	66.0	0.045	0.2	4.9	65.7	0.035	0.06	5.4	0.01	1/0.05
Rush & Brown	67.2	.08	.78	2.8	65.9	.095	.15	3.5	1/.01	-
Copper Center	69.6	.06	.06	1.5	68.1	.085	.03	2.4	-	-

1/ Less than.

Flowsheet

A suggested flowsheet for milling the ores is appended (fig. 3). The flotation cleaner tailing could be rejected or stored for possible subsequent treatment for the production of sulfuric acid and copper and iron byproducts. An alternate plan would include magnetic separation of the original cleaner tailing; this would recover a small amount of additional iron at the expense of grade. The nonmagnetic fraction of this treatment could be either rejected or stored. The cleaner tailing or the nonmagnetic fraction of the cleaner tailing should not be returned to the flotation circuit, however, since it would result in contamination of both final concentrates.

11/ Work cited in footnote 6 (p. 2).

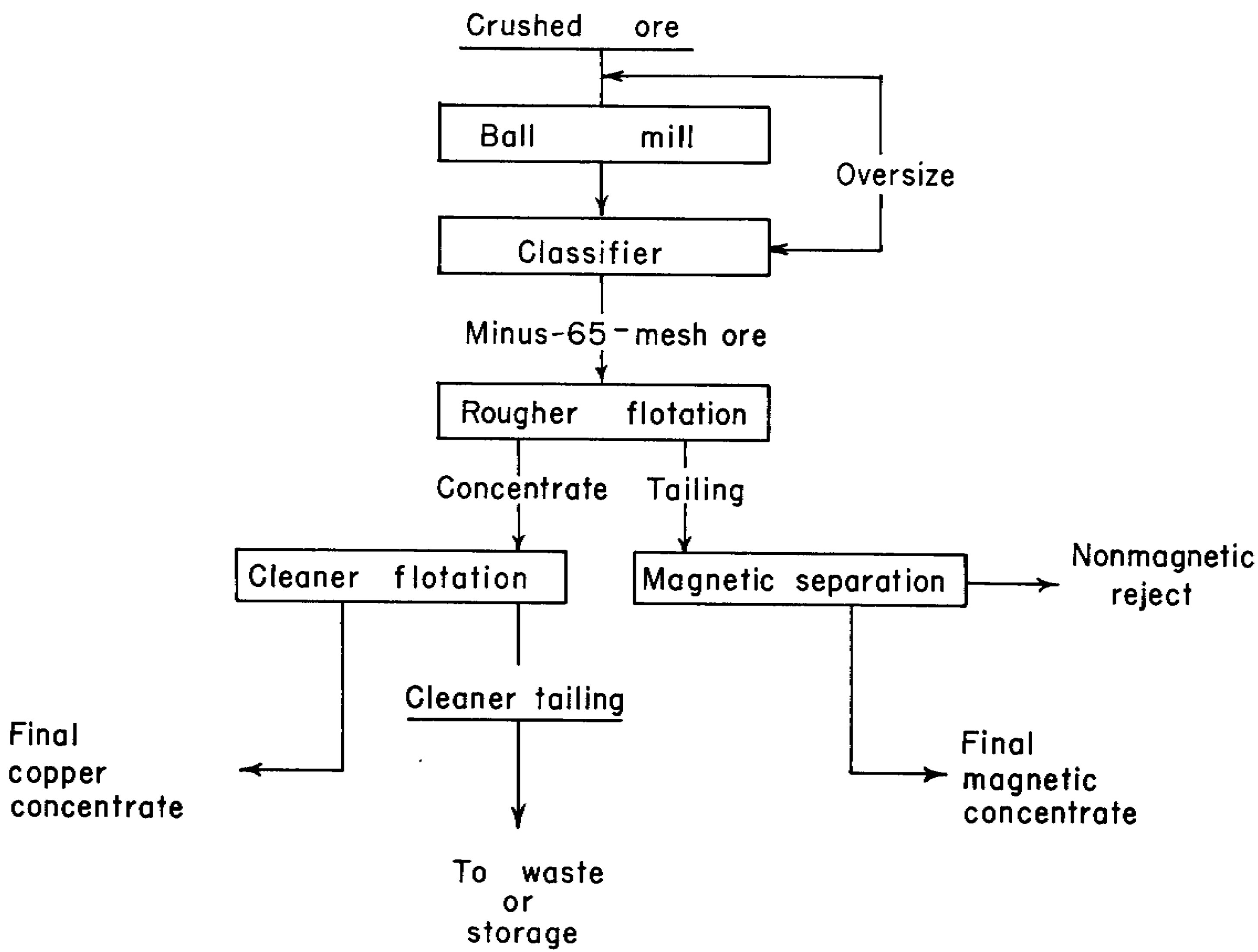

Figure 3. - Suggested flowsheet.