5-1941

The Testing and Concentration of Lake Chelan Copper Ore

Thor W. Johnson

Johnson, T.

THE TESTING AND CONCENTRATION OF A LAKE CHELAN COPPER ORE

By

Thor W. Johnson

A Thesis

Submitted to the Department of Mineral Dressing

in Partial Fulfillment of the

Requirements for the Degree of

Bachelor of Science in Metallurgical Engineering

MONTANA SCHOOL OF MINES

BUTTE, MONTANA

MAY, 1941

THE TESTING AND CONCENTRATION
OF A LAKE CHELAN COPPER ORE

By

Thor W. Johnson

Submitted to the Department of Mineral Dressing
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Metallurgical Engineering

MONTANA SCHOOL OF MINES
BUTTE, MONTANA

MAY, 1941

C O N T E N T S

T A B L E S

THE TESTING AND CONCENTRATION OF A LAKE CHELAN COPPER-GOLD ORE

The purpose of this investigation was to test and attempt to concentrate a copper-gold ore from Lake Chelan, Washington.

The ore studied came from the Lake Chelan district in the North Central section of the State of Washington. As is well known, the Howe Sound Company owns and operates a mine and mill at Holden, Washington, some fifty miles northwest of Chelan, Washington. Mill concentrates from this section of the state are sent to the American Smelting and Refining Company's smelter at Tacoma for smelting and refining. The exact origin of the ore studied by the writer is unknown but the sample bag was marked, "Lake Chelan Copper Ore."

GEOLOGY

The geologic history of the Holden area and Lake Chelan district is an integral part of the history of the Cascade Mountain Range. The structure is very complex and the rocks, which have been subjected to intense metamorphic action, are portions of a roof pendant and consist of gneisses, schists and quartzites that are often difficult to correlate. Many granitic dikes, large and small, and lamprophyre dikes, generally small, are intruded in the formation. Considerable silicification occurred with the ore deposition. Although the geology is complex, the rocks have some characteristics in common; they are all hard and abrasive.[1]

---

1. Curzon, J. J.; Mining Methods Used at Holden Mine," Mining Congress Journal, pp. 10-11 (1941)

The ore examined is essentially a copper ore. This will be shown later by tests performed in determining the minerals present.

The character and association of the gold in the ore body at Chelan has been a matter of much study. The paragenesis of the ore indicates that the gold was introduced at a late stage of mineralization; hence, its intimate association with all of the sulphide minerals and with gangue as free grains.[2]

PROCEDURE IN TESTING

Crushing and Sampling:

About fifty pounds of the ore were available. The maximum size of the ore was approximately six inches. The complete sample was crushed to 3/4 inch size in the Blake jaw crusher in the mill building. After coarse crushing, the ore was passed through small rolls, so set that the product would pass six mesh.

Head Sample Assay:

A Jones splitter was used in sampling the material. Splitting was repeated until about 100 grams remained. This sample was ground on the buck board to pass 100 mesh and assayed. A chemical analysis of the head sample is given in Table I.

Table I

Element	Per cent
Cu	3.1%
Fe	10.9%
Zn	0.69
Pb	0.4
Insol	66.4
Au	0.26 oz. per ton
Ag	0.75 oz. per ton
Sulphide content	18-20%

2Pearse, H. A., and Zanadvoroff, V. A.; "Howe Sound's New Holden Mill," Eng. and Mining Journal. (Nov. 1939) pp. 31

Sizing Analysis

A screen analysis was run on the minus 6 mesh ore sample. Ro-tap screening was employed and the sample was screened for twenty minutes. The results of the screening analysis are presented in Table II.

Table II

MESH	WEIGHT (gms)	WEIGHT %	CUM.WT.%
-6 +8	22.0	5.62	5/62
-8 +10	39.7	10.12	15.74
-10 +14	46.8	11.95	27.69
-14 +20	58.6	14.95	42.64
-20 +28	45.5	11.6	54.24
-28 +35	36.5	9.32	63.56
-35 +48	33.4	8.53	72.09
-48 +65	31.6	8.08	80.17
-65 +100	34.9	8.91	89.08
-100+150	11.6	2.96	92.04
-150+200	7.5	1.91	93.95
-200- -	24.7	6.05	100.00
	391.8	100.00	

Float-and-Sink Analysis:

The next step was the separation of the heavy sulphides from the lighter gangue material. Acetylene tetrabromide, a heavy liquid with a specific gravity of 2.95, was used in these tests. Each of the sized products, with the exception of the minus 200 mesh material, was subjected to float-and-sink tests.

Each screen-sized product of the above 391.8 grams from minus 6 plus 8 mesh was separated by pouring the entire screened product into a 250 cc. beaker, three quarters full of the heavy liquid. The liquid and ore mixture was stirred. The heavy minerals or those with a density greater than the heavy liquid medium, sank, while those particles with a lower density floated. In each case the fraction of the sample which floated was removed with a small wire screened scoop, drained, washed with carbon tetrachloride, dried and weighed. The heavy liquid was drained from the sink material by decantation. This product was thoroughly cleaned with five washes of carbon tetrachloride, dried and weighed.

The finer sizes from minus 48 mesh were separated in a 250 cc. separatory funnel again using acetylene tetrabromide. The sink material was then drawn off through the spigot of the funnel and was collected in a filter paper. After the heavy liquid had drained, the material was washed thoroughly with carbon tetrachloride, drained, dried and wiighed. The float material was drained off and treated in the same way as the sink product.

The results of this treatment are given in Table III.

Table III

MESH	WT. (gms)	WT. SINK (gms)	WT. FLOAT (gms)	% SINK	% FLOAT
-6 +8	22.0	8.5	13.5	38.6%	61.4%
-8 +10	39.7	15.2	24.5	38.3	61.7
-10 +14	46.8	17.0	29.8	36.3	63.7
-14 +20	58.6	20.6	38.0	35.55	64.45
-20 +28	45.5	15.3	30.2	33.61	66.39
-28 +35	36.5	11.5	25.0	31.5	68.5
-35 +48	33.4	9.4	24.8	28.15	71.85
-48 +65	31.6	8.4	23.2	26.58	73.52
-65 +100	34.9	10.7	22.2	30.67	69.33
-100+150	11.6	3.5	8.1	30.18	69.82
-150+200	7.5	3.0	4.5	40.0	60.0
-200	24.7				
	391.8				

MICROSCOPIC STUDY

Preparation of Briquettes;

Lucite and bakelite briquettes of the sink products were made as a preliminary to the microscopic study. Lucite was used as the mounting medium for the products from minus 6 plus 8 mesh to minus 65 plus 100 mesh.

Bakelite was used for sizes smaller than 100 mesh.

In making the lucite briquettes the following details were observed. The mineral sink-products were placed on the bottom plunger of the briquette mold after all surfaces of the mold had been oiled with mineral oil or a special grease. A calculated amount of ground lucite was next added to the mold and then screwed down into position. Heat was applied to the mold by means of an electric coil which surrounds the mold. A pressure of 4000 pounds per square inch was maintained throughout this heating period. A thermometer rested on top of the mold in a small cup of mercury so that the temperature could easily be read. When the mold temperature reached 85° C. the heat was turned off and the cooling device--an electric fan--was started. The briquette was compressed to 10,000 pounds per square inch and kept at this pressure until the temperature had reached about 40° C. By releasing the pressure, the briquette could be removed from the mold by forcing up the lower plunger by means of the jack.

The bakelite briquettes were prepared by a somewhat different procedure, although the same machine and mold were used. The preparation of the bakelite briquettes followed the order given below.

Equal volumes of the ore and minus 200 mesh bakelite were mixed. A sample of this mixture was compressed under 12,000 pounds per square inch in a special mold. This yielded a hard, circular cake of the bakelite and ore about one quarter of an inch thick and one-half an inch in diameter. This cake was then mounted on the bottom plunger of the mold in the same manner as with the lucite briquettes. Minus 65 mesh bakelite in calculated amount was added to the mold. The rest of the treatment closely followed that used in preparation of the lucite briquettes except that the temperature was raised to 50° C. before compression and cooling.

All briquettes were trimmed on the emery wheel. They were then ground by hand using 600 carborundum. The purpose of this grinding was to remove surface pits and to bring the surfaces of the mineral products to a smooth polish. Further grinding was done with minus 10 mesh alundum.. The specimens were then polished with stannic oxide on a broadcloth lap.

Examination under the microscope revealed find scratches, so the specimens were further ground and polished on a mechanical polishing machine using lead laps impregnated with eludriated carborundum or alundum and a kerosene-oil mixture as a lubricant.

This treatment formed a plane surface on the briquette with little relief. All briquettes were not treated on the polishing machine.

Mineral Identification;

The polished briquettes were studied one at a time using the laboratory Metallographic microscope. The writer did not use micro-chemical methods in determining the minerals present, but instead identified the minerals present by their physical properties and measurements. Color is perhaps the most valuable guide to the identification of a mineral.[3] By means of color, crystal habit, and relief, all the more common ore minerals such as pyrite, pyrrhotite, chalcopyrite, sphalerite, arsenopyrite, galena and hematite can be recognized at sight. This is fortunate, for if it were necessary to conduct etching and microchemical tests for each mineral, the amount of time required to examine the briquettes prepared would be prohibitive.

---

[3]Short, M. N.; "Microscopic Determination of Ore Minerals," United States Geological Survey Bulletin 914, pp. 59-170

Hardness was also used as a method of determination. Hardness was measured by scratching with a needle on the surface of the mineral specimen.

Many of the specimens were examined and Table IV presents a resume' of the writer's findings.

Table IV

MINERAL	DETERMINED BY
PYRRHOTITE	Color--bronze to pinkish cream. Hardness--relatively high. Large quantities present.
COVELLITE	Color--indigo blue (one small particle identified)
SPHALERITE	Color--gray (2 or 3 small particles identified)
CHALCOPYRITE	Color--brass yellow Hardness--scratched with needle (distinguished from pyrite) Fairly large amount present.
PYRITE	Color--pale yellow Hardness--not scratched by needle point Large amount present
GALENA	Color--White Crystal habit - cubic - (one sample identified)

The size of liberation was also determined by microscope study. By examining the float-and-sink products
examining the float-and-sink products it was concluded that liberation of the chalcopyrite from the pyrite, pyrrhotite and gangue occurred at approximately 150 mesh. With this data in mind, flotation tests were the next step in this investigation.

FLOTATION TESTS

Introduction

It may be condluded thus far from the study completed that the ore is a copper-gold ore with large amounts of worthless gangue and iron minerals.

The problem then is to eliminate as much gangue and as much iron sulphides as possible within the economic limits. From the geologists' reports on the district it will be noted that the gold is associated with the gangue and the sulphides. The iron in the pyrite and pyrrhotite in itself is worthless and probably detrimental as far as this problem is concerned, but due to the association of the gold, there is a limit as to the amount of iron sulphide that is to be discarded.

The successful separation of chalcopyrite from iron sulphides (pyrite and pyrrhotite) requires the solution of two problems.

1. The first problem is to free the copper mineral from the iron minerals. The size of liberation has already been determined. Fine grinding is always necessary in this kind of problem due to the intimate assodation of chalcopyrite with the pyrite and pyrrhotite.

2. The second problem is to prevent the iron minerals from floating with the copper minerals. This can generally be done in the case of a chalcopyrite and iron sulphides containing no gold by maintaining a pulp strongly alkaline with lime. Lime has a permanent depressing effect on pyrite and pyrrhotite and a very high ratio of concentration can be obtained.[4]

As a rule gold-bearing copper ores present an entirely different problem, ie., ~~that of~~ recovering the gold in the copper concentrate.[4] Free gold is depressed by lime, but Aerofloat can be used as a collector of gold. Soda ash or caustic soda could be used because they do not have a detrimental effect on the gold, but unfortunately they do not depress the pyrite. Their effect is sufficient to keep the pyrrhotite depressed, but pyrite floats

---

[4] Parsons, C. S.: "Selective flotation as applied to Canadian ores," Can. Dept. Mines, Memo.series 29 (1927)

readily. Soda disperses or deflocculates the gangue slimes whereas lime causes flocculates. Soda, however, tends to flocculate the sulphides.[4]

Grinding:

The minus 6 mesh material was sampled by coning and then splitting in a Jones' sampler, until a sample of about 8-10 pounds remained. The material was further ground in a laboratory McCool type pulverizer. This pulverized sample was again split into 600 gram samples. Approximately 10-20% of the pulverized material was minus 150 mesh. This minus 150 mesh material was removed by screening and the plus 150 mesh ore was placed in an Abbé porcelain pebble mill. Flint pebbles were added to approximately 30% of mill volume. The water level was the same as the level of the top of the pebbles. Tap water was used in all grinds. In order to prevent over-grinding, stage grinding was practiced. The ore was ground for a short time, screened and the plus 150 mesh material was returned to the mills for further grinding. This process was repeated until 90% or more of the material passed through the designated screen. The ore was exceedingly hard and required long periods of grinding. The undersize from the 150 mesh screen was about 50% minus 200 mesh. The undersize was transferred to the laboratory 600 gram Fagergren flotation cell for testing.

Reagents:

Table V

REAGENT	FUNCTION	APPROX.CONC. (lb. per ton)
Ethyl Xanthate	collectors	.05-.15
Amyl Xanthate	"	.05-.15
Aerofloat #208	"	.01-.10

[4] Parsons, C. S., op. cit.,

Table V (Cont)

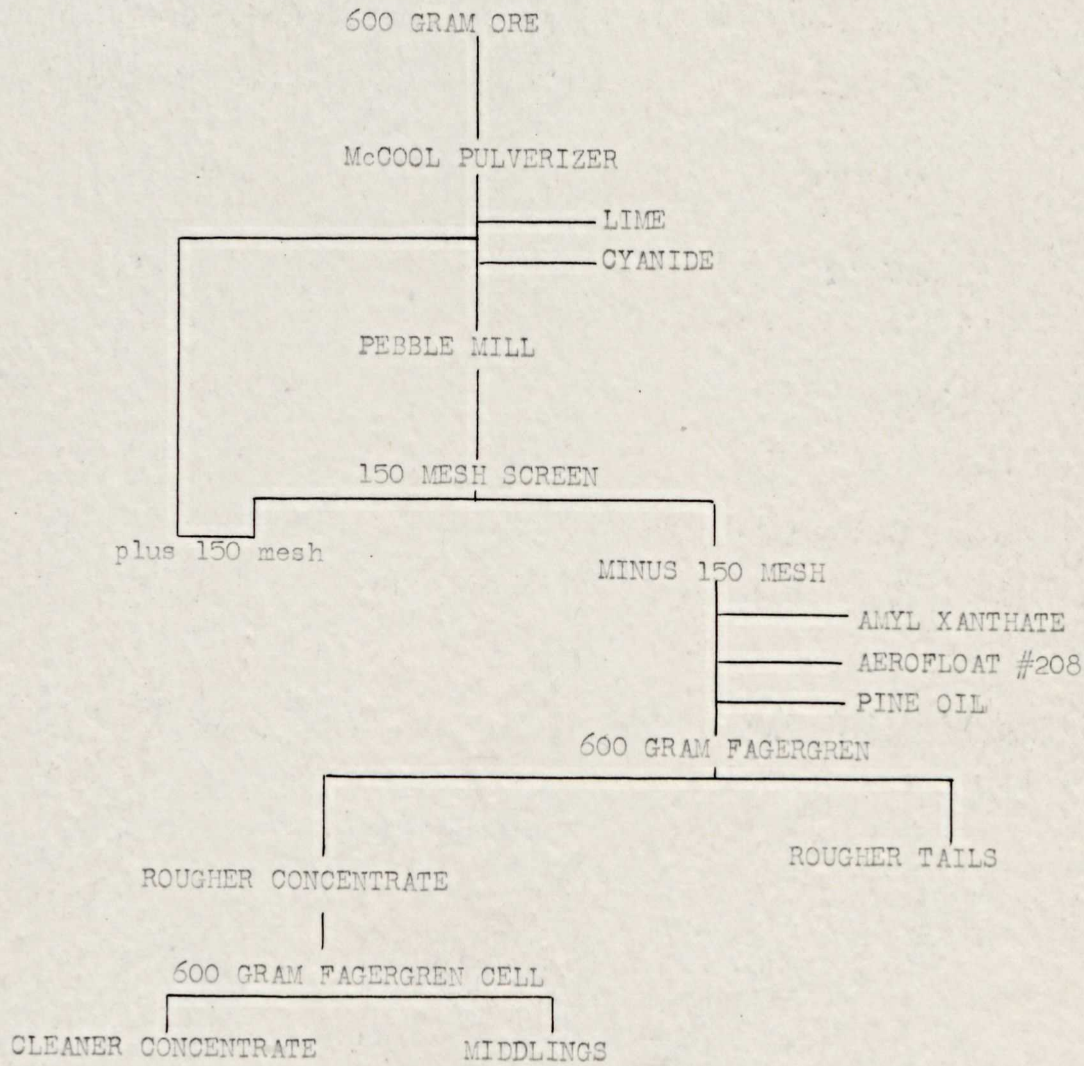
REAGENT	FUNCTION	APPROX. CONC. (lb.per ton)
Lime	conditioners	1.0-10.0
Soda Ash	"	1.0-5.0
Cyanide	"	.03-.75
Cresylic Acid	frother	.05-.2
Pine Oil	"	.05-.2

From the American Cyanamid Company Bulletin- "Flotation Reagents" (1940), the preceding tentative list of reagents was chosen for the preliminary tests. Table V gives the chosen reagents, their function, and suggested quantities.

Flotation Test No. 1 (A Preliminary Test)

This test was run on the minus 150 mesh without the addition of any conditioner. The products, a rougher concentrate, and tailings were weighed and assayed for Au, Ag, Fe and Cu. From the analysis of the products, it can be seen that the reagenys used permitted a high recovery of gold, silver and copper. The iron recovery was not as good as that of the other metals but that did not matter because in this test it showed conclusively that the problem would be to eliminate gangue and depress the iron in order to raise the value of the copper-gold concentrate.

FLOW SHEET OF LABORATORY FLOTATION TESTS



MONTANA SCHOOL OF MINES
Butte, Montana

FLOTATION MEMORANDUM

Date ____________ 193__

Ore No. LC Test No. 1 Ore LAKE CHELAN COPPER ORE

Grind:
Primary Minus 6 mesh Final: Mill Abbe' Mesh Minus 150 Time 10-12-8

Water: Grind tap water Flotation distilled

Percent Solids 26 Flotation machine used FAGERGREN

Product	Weight, grams	Weight percent	Assay, percent				Percent of the Total RECOVERY		
			Au	Ag	Cu	Fe	Cu	Au	Fe
R. Conc.	195	33.0	1.015	1.45	9.48	27.4	98.5	96.9	84.9
R. Tails.	395	67.0	.008	Trace	.13	2.4	1.5	3.1	15.1
Composite	590	100.00	.34	---	3.2	10.7	100.00	100.00	100.00

Reagents	GRIND	COND.	Pounds per ton of crude ore					
KEX		.83						
Aerofloat #208		.5						
Pine Oil		.1						
Time, minutes	30	5						

Remarks: pH - 6.6 Skimmed froth for 5-6 minutes.

MONTANA SCHOOL OF MINES
Butte, Montana

FLOTATION MEMORANDUM

Date ____________ 193__

Ore No. LC Test No. 2 Ore LAKE CHELAN COPPER ORE

Grind:
Primary minus 6 mesh Final: Mill Abbe' Mesh minus 150 Time 10-12-8

Water: Grind tap water Flotation distilled

Percent Solids 26 Flotation machine used FAGERGREN

Product	Weight, grams	Weight percent	Assay, percent				Percent of the Total RECOVERY		
			Au	Ag	Cu	Fe	Au	Cu	Fe
R. Conc.	203	33.8	.81	1.95	8.56	21.7	93.1	83.3	67.9
R. Tails.	397	66.2	.027	.25	.87	5.24	6.9	16.7	32.1
Composite	600	100.0	.29	.83	3.44	10.8	100.0	100.0	100.0

Reagents	Pounds per ton of crude ore							
REAGENTS	GRIND	COND.						
KEX		1.8						
Aerofloat #208		.5						
Pine Oil		.1						
Lime ($Ca(OH)_2$)	.5							
Time, minutes	30	5						

Froth skimmed from 5-6 minutes.

Remarks: pH - 7.6

MONTANA SCHOOL OF MINES
Butte, Montana

FLOTATION MEMORANDUM

Date ____________ 193__

Ore No. LC Test No. 3 Ore LAKE CHELAN COPPER ORE

Grind:
Primary minus 6 mesh Final: Mill Abbe' Mesh minus 150 Time 10-12-8

Water: Grind tap water Flotation distilled

Percent Solids 26 Flotation machine used FAGERGREN

Product	Weight, grams	Weight percent	Assay, percent				Percent of the Total RECOVERY		
			Au	Ag	Cu	Fe	Au	Cu	Fe
R. Conc.	201	33.6	.72	1.88	8.3	23.4	93.0	88.4	73.2
R. Tails	398	66.4	.027	.15	.55	4.35	7.0	11.6	26.8
Composite	599	100.0	.26	.73	3.1	10.7	100.0	100.0	100.0

Reagents	Pounds per ton of crude ore	
	GRIND	COND.
KEX		1.0
Aerofloat #208		.5
Lime	1.0	
Pine Oil		.1
Time, minutes	30	5

Remarks: PH - 8.0 Froth skimmed from 5-6 minutes

MONTANA SCHOOL OF MINES

Butte, Montana

FLOTATION MEMORANDUM

Date ____________ 193__

Ore No. 10 Test No. 4 Ore LAKE CHELAN COPPER ORE

Grind:

Primary minus 6 mesh Final: Mill Abbe' Mesh minus 150 Time 10-12-8

Water: Grind tap water Flotation distilled

Percent Solids 26 Flotation machine used FAGERGREN

Product	Weight, grams	Weight percent	Assay, percent				Percent of the Total		
			Au	Ag	Cu	Fe	Au	Cu	Fe
R. Conc.	184	31.2	.78	1.87	8.69	24.9	94.8	86.3	73.5
R. Tails	406	68.8	.019	.15	.62	4.08	5.2	13.7	26.5
Composite	590	100.0	.26	.68	3.1	10.6	100.0	100.0	100.0

Reagents	Pounds per ton of crude ore	
	GRIND	COND.
KEX		1.0
Aerofloat #208		.5
Lime		.5
Pine Oil		.15
Time, minutes	30	5

Remarks: pH-7.6 Skimmed froth 5-6 minutes

MONTANA SCHOOL OF MINES
Butte, Montana

FLOTATION MEMORANDUM

Date ____________ 193__

Ore No. LC Test No. 5 Ore LAKE CHELAN COPPER ORE

Grind:
Primary minus 6 mesh Final: Mill Abbe* Mesh minus 150 Time 10-12-8

Water: Grind tap water Flotation distilled

Percent Solids 26 Flotation machine used FAGERGREN

Product	Weight, grams	Weight percent	Assay, percent				Percent of the Total RECOVERY		
			Au	Ag	Cu	Fe	Au	Cu	Fe
R. Conc.	184	31.2	.715	2.09	8.55	24.5	93.8	87.5	72.7
R. Tails	405	68.8	.02	.15	.55	4.16	6.2	12.5	27.3
Composite	589	100.0	.24	.754	3.05	10.5	100.00	100.0	100.0

Reagents	Pounds per ton of crude ore	
	GRIND	COND.
KEX		1.0
Aerofloat #208		.5
Lime	1.5	
Pine Oil		.1
Time, minutes	30	5

Remarks: pH - 8.4 Skimmed froth 5-6 minutes

MONTANA SCHOOL OF MINES

Butte, Montana

FLOTATION MEMORANDUM

Date ____________ 193__

Ore No. LC Test No. 6 Ore LAKE CHELAN COPPER ORE

Grind:

Primary minus 6 mesh Final: Mill Abbe' Mesh minus 150 Time 10-12-8

Water: Grind tap water Flotation distilled

Percent Solids 26 Flotation machine used FAGERGREN

Product	Weight, grams	Weight percent	Assay, percent				Percent of the Total RECOVERY		
			Au	Ag	Cu	Fe	Au	Cu	Fe
R. Conc.	193	32.5	.715	2.09	8.55	24.5	94.8	92.2	72.0
R. Tails	400	67.5	.019	.16	.33	4.58	5.2	7.8	28.0
Composite	593	100.0	.25	.78	3.01	11.1	100.0	100.0	100.0

Reagents	Pounds per ton of crude ore	
	GRIND	COND.
KEX		1.0
Aerofloat #208		.5
Lime	2.5	
Pine Oil		.1
Time, minutes	30	5

Remarks: pH - 9.6 Skimmed froth 5-6 minutes

Insol. 38-39%

MONTANA SCHOOL OF MINES

Butte, Montana

FLOTATION MEMORANDUM

Date ______________ 193___

Ore No. LC Test No. 7 Ore LAKE CHELAN COPPER ORE

Grind:

Primary minus 6 mesh Final: Mill Abbe' Mesh minus 150 Time 10-12-8

Water: Grind tap water Flotation distilled

Percent Solids 26 Flotation machine used FAGERGREN

Product	Weight, grams	Weight percent	Assay, percent				Percent of the Total RECOVERY		
			Au	Ag	Cu	Fe	Au	Cu	Fe
R. Conc.	168	28.4	.69	2.21	9.1	20.4	89.4	84.4	52.2
R. Tails	425	71.6	.032	.12	.67	7.4	10.6	15.6	47.8
Composite	593	100.0	.22	.714	3.06	11.1	100.0	100.0	100.0

Reagents	Pounds per ton of crude ore	
	GRIND	COND.
KEX		1.0
Aerofloat #208		.5
Na CN	.1	
Lime	2.5	
Pine Oil		.1
Time, minutes	30	5

Remarks: pH - 9.6 Skimmed froth 5-6 minutes

MONTANA SCHOOL OF MINES
Butte, Montana

FLOTATION MEMORANDUM

Date ____________ 193__

Ore No. LC Test No. 8 Ore LAKE CHELAN COPPER ORE

Grind:
Primary minus 6 mesh Final: Mill Abbe' Mesh minus 150 Time 10-12-8

Water: Grind tap water Flotation distilled

Percent Solids 24.4 Flotation machine used FAGERGREN

Product	Weight, grams	Weight percent	Assay, percent				Percent of the Total RECOVERY		
			Au	Ag	Cu	Fe	Au	Cu	Fe
Cl. Conc.	135	25	1.145	2.81	7.3	31.1	99.6	86.8	68.7
Middlings	60	11.52	.026	.33	.62	6.5			
R. Conc.	185	36.52	.793		5.2				
R. Tails	330	63.48	.01	.14	.20	4.4			
Composite	525	100.0	.289	.829	2.1	11.3	100.0	100.0	100.0

Reagents	Pounds per ton of crude ore	
	GRIND	COND.
KEX		1.0
Aerofloat #208		.5
NaCN	.072	
Lime	2.5	
Pine Oil		.1
Time, minutes	30	5

Remarks: pH - 9.6 Skimmed froth 5-6 minutes

MONTANA SCHOOL OF MINES

Butte, Montana

FLOTATION MEMORANDUM

Date ____________ 193__

Ore No. LC Test No. 9,10,11 Ore LAKE CHELAN COPPER ORE

Grind:

Primary minus 6 mesh Final: Mill Abbe' Mesh minus 150 Time 10-12-8

Water: Grind tap water Flotation distilled

Percent Solids 26 Flotation machine used FAGERGREN

Product	Weight, grams	Weight percent	Assay, percent			Percent of the Total			
			Au	Cu	Fe				
Test 9, Cl. Conc.			.94	10.4					
Test 10, Cl. Conc.			1.19	13.0					
Test 11, Cl. Conc.				13.7	30.4				

Reagents — Pounds per ton of crude ore

	Test #9 GRIND	Test #9 COND.	Test #10 GRIND	Test #10 COND.	Test #11 GRIND	Test #11 COND.		
KAX		1.0		.5		.5		
Aerofloat #208		.5		.5		.5		
Lime	2.5		2.5		3.0			
NaCN	.083		.15		.2			
Pine Oil		.1		.1		.1		
Na SiO_3				.5		.5		
Time, minutes	30	5	30	5	30	5		

Remarks: In Test No. 10 and 11, $NaSiO_3$ was added in cleaning stage in an effort to cut down the gangue materials that floated.

MONTANA SCHOOL OF MINES
Butte, Montana

FLOTATION MEMORANDUM

Date ____________ 193__

Ore No. LC Test No. 12 Ore LAKE CHELAN COPPER ORE

Grind:
Primary minus 6 mesh Final: Mill Abbe Mesh minus 150 Time 10-12-8

Water: Grind tap water Flotation distilled

Percent Solids 26 Flotation machine used FAGERGREN

Product	Weight, grams	Weight percent	Assay, percent			Percent of the Total			
			Au	Cu	Fe				
Cleaner "A"	71	11.82	1.96	20.7	30.4				
Cleaner "B"	25	4.17	.305	4.46	26.7				

Reagents	Pounds per ton of crude ore								
	GRIND	COND.							
KEX		.5							
Aerofloat #208		.33							
Lime	2.5								
KCN	.16								
Pine Oil	(.04)lb	per ton	to conditioner to get Cleaner "A"						
" "	.04lbs.	per ton	additional to get Cleaner "B"						
Time, minutes	30	5							

Remarks: pH - 9.5

Cleaner "A" frothing for 1½ minutes -- Cleaner "B" frothing for 2 minutes.

MONTANA SCHOOL OF MINES
Butte, Montana

FLOTATION MEMORANDUM

Date ____________ 193__

Ore No. LC Test No. 13 Ore LAKE CHELAN COPPER ORE

Grind:
Primary minus 6 mesh Final: Mill Abbe' Mesh minus 150 Time 10-12-8

Water: Grind tap water Flotation distilled

Percent Solids 26 Flotation machine used FAGERGREN

Product	Weight, grams	Weight percent	Assay, percent				Percent of the Total RECOVERY		
			Au	Cu	Fe		Au	Cu	Fe
Cleaner Conc.	72	12.0	2.315	21.6	28.8		91.6	89.6	42.1
Middlings	63	10.5	.07	11.9	11.6				
R. Tails	465	77.5	.035	.58	8.3		8.4	10.4	57.9

Reagents	Pounds per ton of crude ore							
	GRIND	COND.						
KAX		.5						
Aerofloat #208		.33						
Lime	3.5							
KCN	.5							
Pine Oil		.04						
Time, minutes	30	5						

Remarks: pH - 10

3 Minutes Roughing --- 2 Minutes Cleaning.

MONTANA SCHOOL OF MINES
Butte, Montana

FLOTATION MEMORANDUM

Date ____________ 193__

Ore No. LC Test No. 14 Ore LAKE CHELAN COPPER ORE

Grind:
Primary minus 6 mesh Final: Mill Abbe' Mesh minus 150 Time 10-12-8

Water: Grind tap water Flotation distilled

Percent Solids 26 Flotation machine used FAGERGREN

Product	Weight, grams	Weight percent	Assay, percent					Percent of the Total RECOVERY	
			Au	Ag	Cu	Fe	Insol.	Au	Cu
Cleaner Con.	82	13.92	1.675	4.03	19.75	31.3	12.0	99.5	92.0
Middlings	57	9.68	.10	.95	2.43	22.8	46.4	.42	7.86
R. Conc.	139	23.60	.995	2.76	12.65	66.8	26.1	99.92	99.96
R. Tails	450	76.4	.025	.10	.15	5.9	83.0	.08	.14
Composite	589	100.0	.254	.73	3.07	11.1	69.6	100.0	100.0

Reagents	GRIND	COND.	Pounds per ton of crude ore					
KAX		.33						
Aerofloat #208		.23						
Lime	2.0							
KCN	.2							
Pine Oil		.04						
Time, minutes	30	5						

Remarks: pH - 9.4

Roughing - 3 minutes Cleaning - 3 minutes

DISCUSSION OF RESULTS

Flotation tests Nos. 2, 3, 4, 5 and 6 were run to ascertain the effect of changing the pH by the addition of lime to the circuit. It was thought at first that an alkaline circuit would depress some iron sulphide. It was found, however, that changes in alkalinity in the absence of cyanide had very little effect in depressing the iron sulphides. The gold and copper recoveries were not affected except in Test No. 6 where the alkalinity was high (pH of 9.6) In this test the recoveries were better than in the tests at lower pH. value, ranging in Cu recovery from 83.3% with a pH. of 7.6 to 92.2% with a pH. of 9.6. The gold recovery was little affected, although there was an increase from 93.1% with a pH of 7.6 to 94.8% with a pH. of 9.6. In test No. 4 the lime was added to the conditioner instead of at the grinding stage in order to determine at which point it should be added. The test was not necessary as the series of tests on alkalinity control did not accomplish much. However, in practice the lime and any other modifying agent are generally added to the ball mill so the new surfaces may be altered before conditioning in the flotation cells.

In test No. 7, 0.110 lb. sodium cyanide per ton was added. The copper recovery decreased to 84.4% and the gold recovery was lowered to 89.4%. However, the iron was depressed so that 52.2% iron remained in the rougher concentrate.

In test No. 8 the rougher concentrates were cleaned, but the copper content and recovery were low. Study of a briquetted cleaner concentrate showed that there was too much gangue material floating. A chemical analysis showed 38% insol. present. This high gangue percentage could be due to; flocculation of the gangue particles; to "over-roughing and over cleaning;" or to the use of too much frother.

Flotation tests Nos. 9,10 and 11 indicate the results of the writer's intentions of raising the grade of copper in the cleaner concentrate by decreasing the percentage of gangue and iron sulphides. To Tests 10 and 11, sodium silicate was added as a dispersant in the cleaning operation. The copper grade was brought up to 13.0% and 13.7% in tests 10 and 11, respectively, but it was not determined whether the increase in grade was due to the addition of the sodium silicate or to the increase in sodium cyanide used, which undoubtedly depressed the iron sulphides. It was thought that the sodium cyanide added was the determining factor because the ratio of concentration was only about 4.7:1 indicating the presence of much useless gangue.

Flotation Test No. 12 was run to determine the length of the time of frothing and the optimum amount of frother needed. The pH. was 9.5. One drop of pine oil or an equivalent of 0.04 lb. per ton was added and a first cleaner concentrate "A" was removed for 1½ minutes and the analysis of the product indicated that most of the copper floated first. The second cleaner was removed as a result of adding another drop of pine oil and was skimmed off for two minutes. This froth was dirty and contained a large per cent of iron, sulphide, mostly pyrrhotite and siliceous gangue and some copper and gold.

Table XVI gives the results of flotation Test No. 13 in which the writer tried to add the maximum practical amount of lime and cyanide. The pH. was 10. The results were good, with 91.6% recovery of gold and 89.6% recovery of copper in the cleaner concentrate and the middlings together.

The amount of KCN added (.51 lb. per ton) evidently affected the chalcopyrite since the rougher tails assayed .58% Cu. The cleaner concentrate recovered in this test had the highest copper assay that was obtained in all tests performed. It was suggested that the pH. of 10 may be high so in Test No. 14 the amount of lime and KCN was decreased and the test was operated at a lower alkalinity. Flotation Test No. 14 gave the best results. The recovery of the gold and copper in the cleaner concentrate and the middlings was over 99%. Great care was excercised throughout this test. Ration of concentration was 7.5:1 with only 12% insol. in the cleaner concentrate; the pH. was 9.4. It is from the data and knowledge obtained from this test that the following suggestions for further study, and the conclusions are drawn.

CONCLUSION

A copper-gold concentrate containing a maximum of 20% copper and 1.675 oz. of gold per ton of ore was recovered. The recovery of both the copper and the gold was over 90%. It is quite probable that a concentrate of 24-25% Cu could be recovered by further elimination of the iron sulphides and gangue.

Gold was found to occur chiefly with the chalcopyrite and pyrites.

Comparison can be made with the results of the ore studied and the results obtained from the copper ore milled at Britannia Mill at Britannia Beach, British Columbia, Canada. The association of chalcopyrite and pyrite and their relative amounts in both ores are comparable. Therefore, because of these comparisons, the proposed flow sheet which follows is similar to that of the flow sheet at Britannia although simplified greatly. At Britannia, also, tables are employed to recover a pyrite concentrate which is later utilized in the manufacture of sulphuric acid.

If a large ore body exists, the erection of a flotation mill would be warranted.

SUGGESTIONS FOR FURTHER STUDY

A more complete study of this copper gold ore would entail some of the following considerations:

1. Different pulp densities should be considered and tested. Gaudin suggested pulp densities from 20% solids to 40% solids.[5]

2. Iron sulphides should be more completely depressed. This can be accomplished by determining by tests the proper amounts of depressant which should be added in order that the chalcopyrite will not be affected.

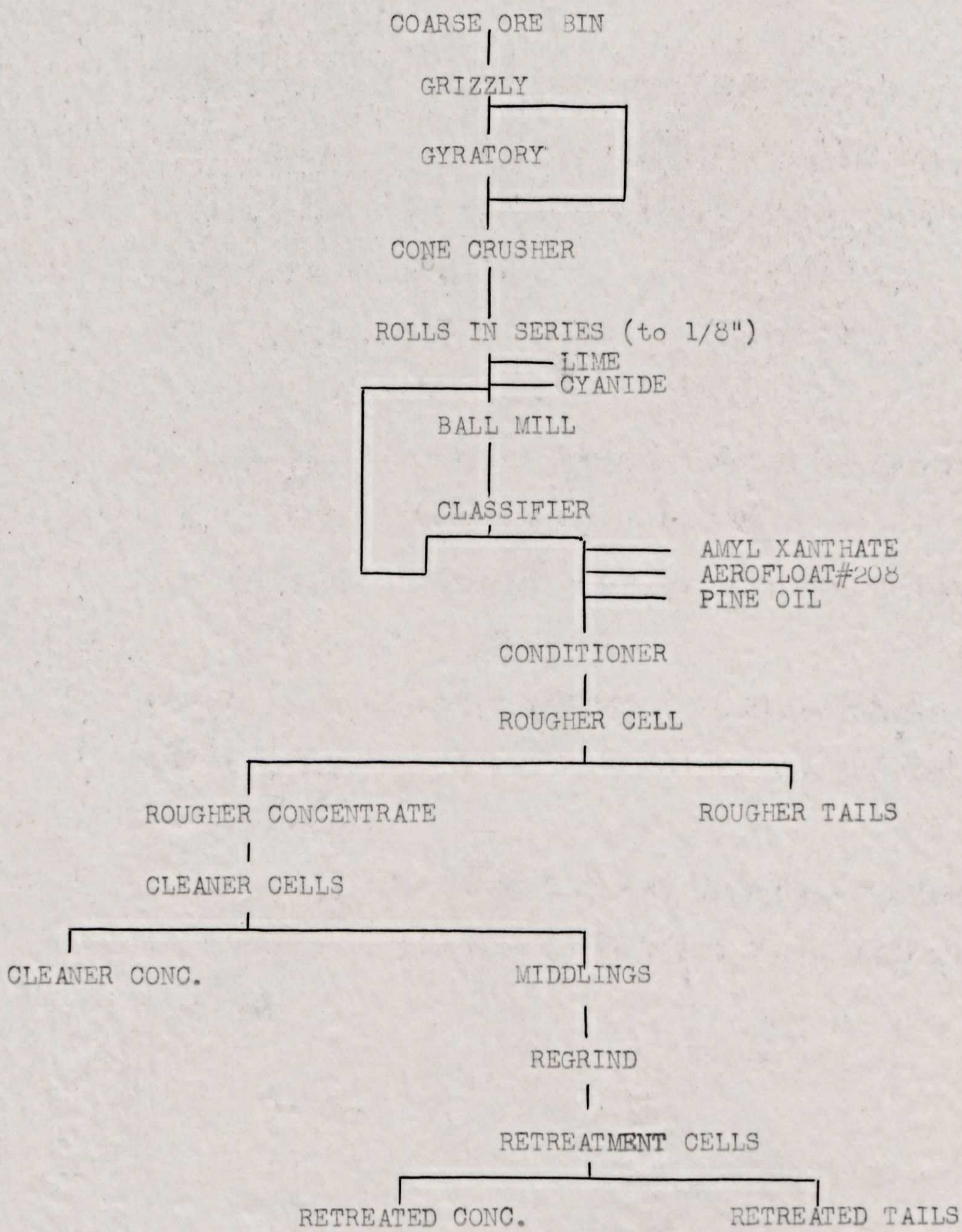
3. Proper alkalinity could be found only by tests of varying pH. values.

4. The effect of varying amounts of reagents should also be studied in order to determine the least amount required to obtain a maximum recovery.

---

[5] Gaudin, A. M., Principles of Mineral Dressing (New York, 1939), p.

SUGGESTED FLOW SHEET



BIBLIOGRAPHY

1. Curzon, J. J.: Mining Methods Used at Holden Mine," Mining Congress Journal, pp. 10-11 (1941)

2. Pearse, H. A., "The Concentration of Britannia Ore," Canadian Mining and Metallurgical Bulletin, Vo. 20, Part 2, (1927) pp. 1314-1320.

3. Pearse, H. A., "Howe Sounds New Holden Mill," Engineering and Mining Journal, (Nov. 1939) pp. 31.

4. Zandvoroff, V. A., "Howe Sound's New Holden Mill," Engineering and Mining Journal, (Nov.1939) pp.31.

5. Short, M. N., "Microscopic Determination of Ore Minerals," United States Geological Survey Bulletin 914, pp. 59-170.

6. Parsons, C. S., "Selective Flotation as applied to Canadian Ores." Can. Dept. Mines, Memo. series 29 (1927).

7. American Cyanamid Bulletin, "Flotation Reagents"lo (1940)

8. Gaudin, A. M., "Flotation," McGraw-Hill Book Company, Inc., New York (1932) pp. 157-161.

9. Gaudin, A. M., Principles of Mineral Dressing, New York,(1939) p.403

10. Report of Investigations - 3328, United States Bureau of Mines.

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation and gratitude to Dr. S. R. B. Cooke, head of the Mineral Dressing Department, for his suggestions in the work represented by this thesis.

The writer is also indebted to Mesrs. Carlos Plenge, Robert Wilson and Ed Swanson for suggestions and aid they rendered.