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# A Preliminary Study of Montana Copper - Nickel Ore

J. Argall McAllister

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McALLISTER A PRELIMINARY STUDY OF MONTANA COPPER NICKEL ORE

A PRELIMINARY STUDY OF  
MONTANA COPPER - NICKEL ORE

By  
*J. Argall*  
J. Argall McAllister

A Thesis  
Submitted to the Department of Metallurgy  
in Partial Fulfillment of the  
Requirements for the Degree of  
Bachelor of Science in Metallurgical Engineering

MONTANA SCHOOL OF MINES

BUTTE, MONTANA

MAY, 1936

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A PRELIMINARY STUDY OF  
MONTANA COPPER - NICKEL ORES

Deposits of sulfides, containing nickel and copper with associated platineferous minerals occur in the Stillwater igneous complex, a group of unusual igneous rocks, situated in Stillwater and Sweetgrass counties, Montana. The deposits so far uncovered are low grade and as yet have no economic significance. A full description of the complex is given in a recent publication of the Montana Bureau of Mines and Geology, entitled, "Miscellaneous Contribution No. 7--"The Stillwater Igneous Complex and Associated Occurrences of Nickel and Platinum Group Metals."

The ore under investigation comes from the Mouat property on the west side of Stillwater valley. The Mouat mine is the largest of the two nickel properties in the district. Sulfides occur in hornfels and vary from sparse disseminations to massive sulfide with less than ten per cent silicates. The metallic minerals are pyrrhotite, chalcopyrite and pentlandite with small amounts of pyrite.

The results of assays on a sample taken from the dump of the Mouat mine and determined by the International Nickel Co. of Canada, are shown in the first column of the following table. A - 100 mesh sample cut from the ore used in experimental work and analyzed by the

Montana Bureau of Mines and Geology gave the results shown in the second column.<sup>1</sup>

Table I

Determination	Assay	
	Int. Nickel Co.	Mont. B. M. & Geol.
Copper	1.85%	2.25%
Nickel	0.55%	0.58% <sup>1</sup>
Iron		31.40%
Platinum metals	0.0085 oz/ton	
Palladium	0.0025 oz/ton	
Gold	0.0020 oz/ton	

Identification

In order to ascertain its mineralogical characteristics, a number of polished sections of the ore were examined under the microscope. Pentlandite and pyrrhotite are very difficult to differentiate under the microscope because both have similar colors. In some of the polished sections examined, it was possible to distinguish between pentlandite and pyrrhotite by changing the focus slightly.

The chromic acid stain described by Professor

<sup>1</sup>

All assays for copper and iron given in this study were determined by the Montana Bureau of Mines and Geology. All nickel determinations were made by the writer, following the scheme outlined in H. A. Pales, "Inorganic Quantitative Analysis."

A. H. Gaudin in Economic Geology, Volume 30, pages 552 to 562, was used to differentiate the ore minerals. When the polished ore surface is stained for a certain length of time with a chromic acid solution, the pentlandite assumes a bright blue color, the pyrrhotite turns a dark bronze and the chalcopyrite retains its original color.

#### Mineralogy and Occurrences

Pyrrhotite is far more abundant than chalcopyrite and pentlandite. Pyrrhotite, chalcopyrite and pentlandite are interstitial to and partly replacing the silicate.

Pentlandite is clearly replacing pyrrhotite in places and also occurs in small grains in the silicate. Pentlandite also occurs in a bead like sequence along twinning planes and faces of the pyrrhotite. Nickel also seems to occur as a solid solution in pyrrhotite.

Chalcopyrite may be intergrown with pyrrhotite and pentlandite but usually occurs separately in the silicate as free chalcopyrite. Two different types of silicates were in evidence, one being a darker gray than the other.

Pyrite occurs in the silicate and rarely in contact with other minerals. See Plate I, for typical appearance of specimens under the microscope.

### Grinding Tests

A number of grinding tests were made in which 500 grams of ore were ground with 400 c.c. of water in a 500-gram-capacity pebble mill. Sizing was done entirely by screening because of the inherent difficulties of sizing magnetic products by sedimentation, pyrrhotite being very magnetic and tending to flocculate when in a finely divided and suspended state. Sizing tests were run on products which had been ground as described above, for twenty minutes, forty minutes, and sixty minutes.

The grinding time decided on as being the best, was the thirty minute grind, or so that 90% of the pulp will pass through a 270 mesh Tyler screen. The advantage of freeing the minute grains of pentlandite by excessive fine grinding is offset by the tendency of pyrrhotite to flocculate and include the free grains in the floccules.

### Flotation Experiments

A few flotation experiments have been conducted, the purpose of which were twofold:

- 1.-To separate the valuable constituents  
(pentlandite, pyrrhotite, chalcopyrite)  
from the gangue.
- 2.-To separate the valuable minerals from each  
other.



Tests I to VI

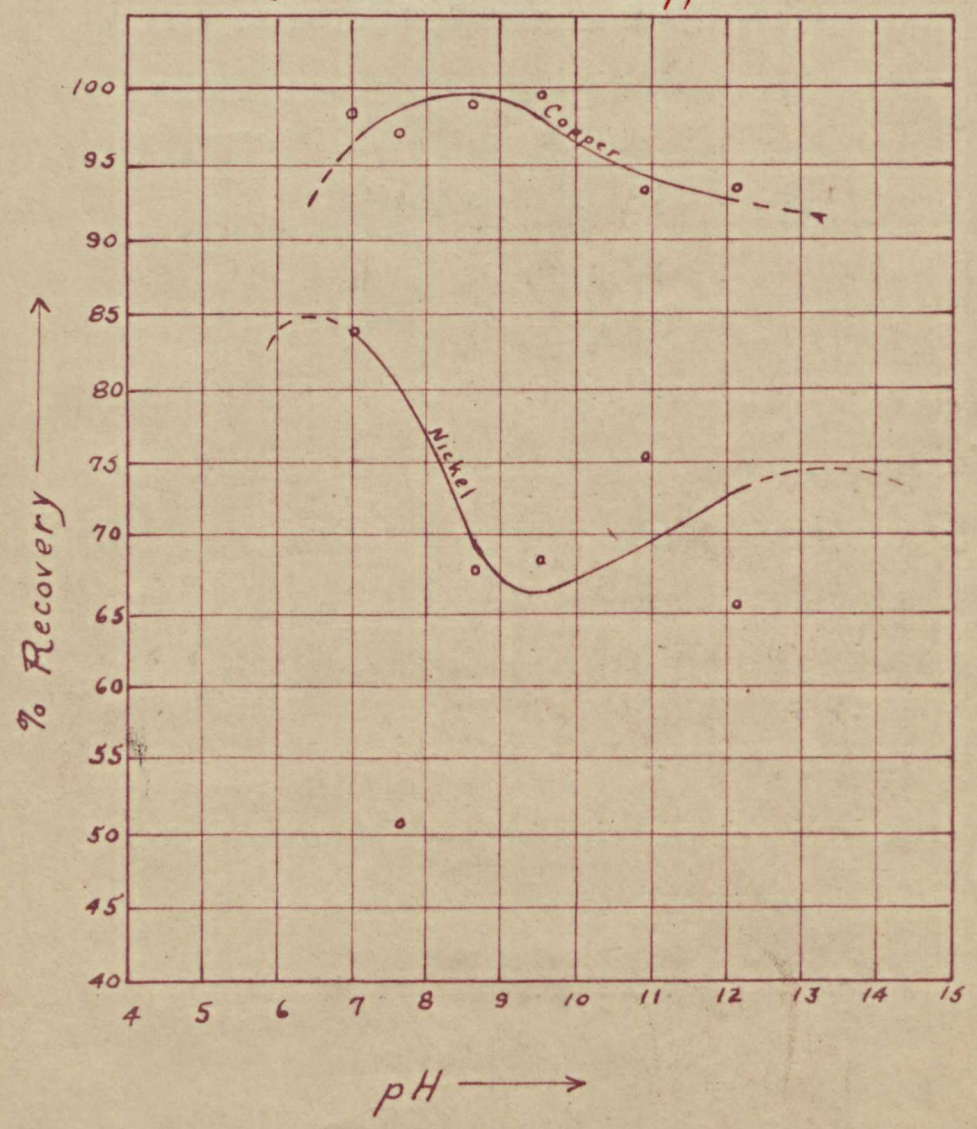
Object: To find out the effect of a varying pH upon the recoveries of nickel and copper.

A sequence of flotation tests were made, using approximately 0.10 lb./ton of amyl xanthate and 0.07 lb./ton of terpineol on each run. Standard buffer solutions were used to maintain a predetermined pH. The method of making up these standard buffer solutions is described in Clark, "The Determination of Hydrogen Ions," Chapter IX. Graph I, constructed from data obtained from Table II, shows the detail of the results obtained. A maximum recovery of copper was obtained at a pH of about 8.5, and the maximum for nickel at a pH which is substantially lower, that is, at about 7.0.

Table II

Test	pH Desired	pH Obtained	Weight		Concentrate Tailings						Recovery		
			Feed	Conc.	Tails	% Cu	% Ni	% Fe	% Cu	% Ni	% Fe	% Cu	% Ni
1	7.0	7.0	534.8 G.	300.8 G.	234.0 G.	3.70	0.69	36.6	0.18	0.18	0.6	98.4	84.0
2	8.0	7.6	478.1 "	229.6 "	248.5 "	5.00	0.41	38.6	0.13	0.35	4.6	97.4	82.1
3	9.0	8.6	498.7 "	268.2 "	230.5 "	4.49	0.37	38.1	0.05	0.20	3.0	99.0	88.0
4	10.0	9.5	539.0 "	268.5 "	270.5 "	4.69	0.36	36.5	0.03	0.18	2.7	99.4	88.6
5	11.0	10.9	524.0 "	225.0 "	299.0 "	4.70	0.77	38.0	0.25	0.19	4.6	93.5	75.6
6	12.0	12.1	434.5 "	200.5 "	234.0 "	5.00	0.62	35.7	0.20	0.29	17.9	93.5	65.2

Graph I  
Effect of pH on The Recovery  
of Nickel & Copper



Test VII

Object: To observe the effect of cyanide on the recovery of nickel when used to depress pyrrhotite.

In this test, 2000 grams of ore was ground for thirty minutes with 1000 c.c. of water and 5 lb./ton of lime, which gave a pH of 8.7 at the start of the test. A 2000-gram-capacity Denver Sub-A flotation machine, with a pulp dilution of about 5½ to 1 was used. Using xanthate and terpineol as reagents, a froth was made which was re-floated in the 500-gram-machine, using cyanide to depress the pyrrhotite. The recovery of copper was 97% but that of the nickel totaled only 46.4%. The cleaner tailings showed a higher percentage of nickel than the copper concentrate. See Tables III & IV below.

Table III

<u>Place of Addition</u>	<u>Reagent Consumption (lb./ton)</u>			
	<u>Amyl Xanthate</u>	<u>Terpineol</u>	<u>Cyanide</u>	<u>Lime</u>
During grind	----	----	----	----
Bulk flotation	0.10	0.075	----	-5.0
Cleaner "	0.05	0.05	----	----

Table IV

Product	pH	Wt.	Assay			Recovery	
			% Cu	% Ni	% Fe	Cu %	Ni %
Bulk concentrate	8.7	--	--	--	--	--	--
Cleaner "	8.0	470 g.	9.10	0.46	38.3	97.0	31.4
Cleaner tailings		148 "	0.15	0.71	44.2	0.07	15.0
Bulk Flotation tails		1310 "	0.07	0.29	19.5	2.93	53.6

Test VIII

Object: To see if regrinding would improve the recovery.

2000 grams of ore was ground for thirty minutes with 1000 c.c. of water and 10 lb./ton of lime. Two successive froths were floated. 500 grams of the tailings from the above operation was ground for 20 minutes with 0.05 lb./ton of copper sulfate and 5 lb./ton of soda ash. A concentrate and tailing were made from this reground pulp. In this experiment, the nickel content was boosted to 1.5% in the 10% copper concentrate. Regrinding seemed to prove of little value, due to the behaviour of the finely ground pyrrhotite. See Tables V & VI below.

Table V

<u>Place of Addition</u>	<u>Reagent Consumption (lb./ton)</u>				
	<u>Amyl Xanthate</u>	<u>Terpineol</u>	<u>Lime</u>	<u>Soda Ash</u>	<u>CuSO<sub>4</sub></u>
During grind	----	----	10.0	----	----
First froth	0.05	0.025	----	----	----
Second "	0.05	0.050	----	----	----
During regrind	----	----	----	5.0	0.05
Scavenger conc.	0.07	0.05	----	----	----

Table VI

<u>Product</u>	<u>pH</u>	<u>Time</u>	<u>Weight</u>	<u>Assay</u>			<u>Recovery</u>		
				<u>% Ni</u>	<u>% Cu</u>	<u>% Fe</u>	<u>Ni %</u>	<u>Cu %</u>	<u>%</u>
First froth		6 min.	197 g.	1.58	9.76	35.7	28.0	62.8	
Second "	10.3	26 "	363 "	1.06	2.95	44.3	34.6	35.0	
Tailings		----	1375 "	0.30	0.05	18.8	37.4	2.2	
Scavenger Conc.	8.4	----	56 "	0.50	0.82	20.3	18.2	81.0	
" tails		----	430 "	0.29	0.25	18.4	81.7	19.0	

Discussion

As is seen from the data, the best copper concentrate made assayed only 10% copper and 1.5% nickel. Attempts to make a nickel concentrate failed. It was impossible to lower the grade of the tailings to less than 0.3% nickel.

It is desirable to know if the present deposits of copper and nickel can be economically worked. To come to a sound conclusion, the following assumptions were made:<sup>1</sup>

1. A 15% copper concentrate containing 2% nickel can be made with an 80% recovery of copper from the ore which assays 2.25% copper and 0.58% nickel.

$$\text{Ratio of concentration} = \frac{15}{2.25 \times 0.80} = 8:1$$

2. Payment for copper: If 3% or more, pay for 90% of dry assay at 9 cents less 3 cents per lb.

3. Payment for nickel: It is doubtful if a copper smelter would pay for the nickel, so it is assumed:

- a. Pay for all the nickel at 30 cents per pound.
- b. No payment for nickel.

4. Treatment charge on 3% copper, \$3.00 base. Reduce charge by 10 cents for each unit in excess of 3% (dry).

5. Cost of milling is \$1.00 per ton.

6. Cost of transportation is \$5.00 per ton of concentrate.

<sup>1</sup>A. H. Gaudin, "Flotation", Chapter XVII

		Dollars per Ton of Concentrate		
		Credit (a) <sup>1</sup>	Credit (b) <sup>2</sup>	Debit
Copper:	$0.90 \times (15.0) \times 20 \times (0.09 - 3)$ . . . .	\$15.12	\$15.12	
Nickel:	$2.0 \times 20 \times 0.30$ . . . . .	12.00		
Treatment:	$3.00 - (14.0 - 3.0) \times 0.10$ . . . . .			1.90
		<hr/>		
		27.12	15.12	1.90
		<hr/>		
		1.90	1.90	
		<hr/>		
Net smelter payment per ton dry concentrate . . .		25.22	13.22	
Transportation . . . . .				5.00
		<hr/>		
		5.00	5.00	
		<hr/>		
Receipt per ton concentrate . . . . .		20.22	8.22	
Receipt per ton of ore (R. C. = 8:1) . . . . .		2.54	1.03	
Cost of milling per ton ore . . . . .		<u>1.00</u>	<u>1.00</u>	
Net receipts per ton of ore . . . . .		1.54	0.03	
To be charged against the above receipts: Cost of mining and profit.				

Case (a) It is well known that most forms of metal vein mining would cost more than \$1.54 per ton. Also to be considered is the fact that a return on investment is expected.

Case (b) It is obvious that if the smelter does not pay for the nickel, exploitation of the ore is not to be considered.

<sup>1</sup> Smelter pays for nickel.

<sup>2</sup> Smelter does not pay for nickel.



Conclusions

1.-A copper concentrate containing a maximum of 10% copper and 1.5% nickel can be made from this ore. However, the possibility of raising the grade of the copper concentrate to 15% is not remote.

2.-It is doubtful if a nickel concentrate, as such, can be made.

3.-It seems impossible to lower the grade of tailings to less than 0.3% nickel. This suggests that part of the nickel occurs as a silicate.

4.-Flotation concentration of Montana copper-nickel deposits will not be economically justifiable, unless:

a.-Higher grade ore is discovered.

b.-An unprecedented shortage or demand forces the price of copper and nickel to far above their present market quotations.

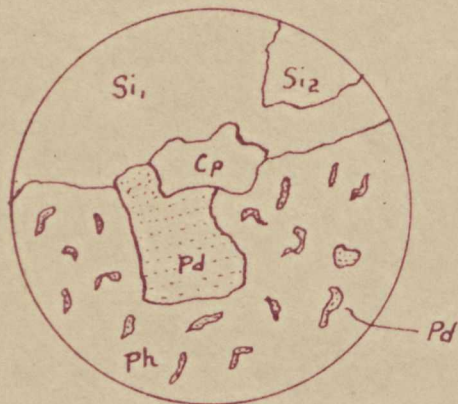
Acknowledgments

I take this opportunity to express my gratitude to Professor A. H. Gaudin, head of the Department of Ore Dressing at the Montana School of Mines, under whose direction this work has been done, for his aid and assistance and for the reading of the manuscript.

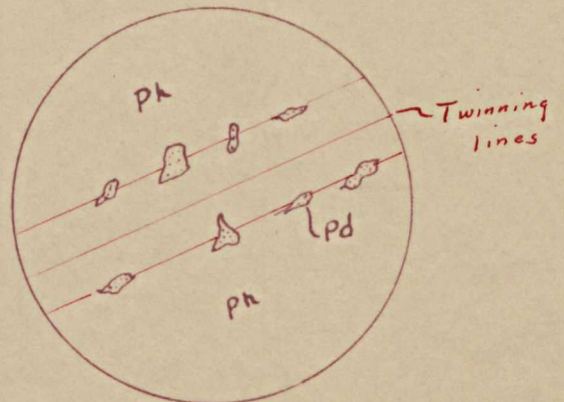
I am also indebted to Professor L. J. Hartzell and J. W. Johns, Jr. for timely suggestions and loan of equipment.

Appendix

Plate I



100 x



60 x

- X-----diameters
- Si<sub>1</sub>-----dark colored silicate
- Si<sub>2</sub>-----light " "
- Cp-----chalcopyrite
- Ph-----pyrrhotite
- Pd-----pentlandite