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INVESTIGATION OF SOME VARIABLES AFFECTING FLOTATION OF ORE FROM STANLEIGH URANIUM MINING CORPORATION, LTD., ELLIOT LAKE, ONTARIO

by

W. R. HONEYWELL AND W. A. GOW

EXTRACTION METALLURGY DIVISION

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INVESTIGATION OF SOME VARIABLES AFFECTING FLOTATION OF ORE FROM STANLEIGH URANIUM MINING CORPORATION, LTD. ELLIOT LAKE, ONTARIO

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SUMMARY OF RESULTS

In a series of laboratory scale flotation tests carried out on Stanleigh mill-ground ore an optimum recovery of 89.7% of the uranium was obtained in 45.4% of the weight at a grade of 0.22% U_3O_8 from deslimed ore containing 0.11% U_3O_8. Desliming of the ground ore before flotation was necessary, and also it was necessary to soften the mill water before use. The mill-ground ore had more uranium in the slime fraction than the laboratory-ground ore, and so was less amenable to flotation.

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INTRODUCTION

This report covers an investigation of the cause of the variance between the flotation results obtained at the Stanleigh mill and at the Mines Branch laboratory.

During April and May 1959, Mr. D. Raicevic at Stanleigh Uranium Mining Corporation Limited, Elliot Lake, Ont., did a number of flotation tests with the purpose of producing a uranium-bearing preconcentrate for subsequent leaching. Some of these tests were based on methods and reagents, which had been used at the Mines Branch. However, the results at the mine were not as satisfactory as those obtained at the Mines Branch and reported in Mines Branch Technical Bulletin TB 2 (1).

Consequently, in May 1959, the writers visited Mr. Raicevic at the Stanleigh operation to discuss these flotation problems with him. During these conversations, it became apparent that there were several areas of difference between the conditions and procedure outlined in the Mines Branch report and those being used by the Stanleigh investigators. The differences noted are shown in Table 1.

TABLE 1

Comparison of Stanleigh and Mines Branch Flotation Procedures

	Mines Branch Procedure(1)	Stanleigh Procedure
pH	8.5 - 9.5	slightly acid
Water temperature	20 - 25°C	10 - 12°C
Type of water	distilled	hard plant water
Deslimed	yes	no
Flotation cell type	Fagergren	Denver
Grind	Batch lab grind	Plant grind

The test work described in this report was done to determine, if possible, to what extent the poor flotation results obtained in the Stanleigh tests could be attributed to the difference in technique at the two laboratories and to determine means of bringing the plant test procedure more in line with that of Mines Branch if necessary.

DETAILS OF TEST WORK

Description of Samples

All the flotation tests in this work were done on samples of ore pulp taken from the classifier overflow of the Stanleigh grinding circuit. The pulp samples sent to the Mines Branch were not filtered at the plant but were shipped as taken in polyethylene carboys. Two pulp samples, taken at different times, were used in this work and are designated as samples A and B in this report. In addition to the pulp samples, carboys of Stanleigh plant water were also obtained for use as dilution water in the test work.

The uranium contents of the various flotation test feed samples varied from 0.11-0.13% U_3O_8. These figures were obtained by calculation from chemical analysis of the flotation products.

Mineralogy of the Ore

The mineralogical report (2) on a sample of drill core from the "ore zone" on the Company's property states that brannerite is the most abundant radioactive mineral in a coarse quartz pebble conglomerate. Uraninite is also fairly common while monazite is quite scarce. Brannerite, the coarsest of the radioactive minerals, does not exceed 1 mm in size.

The matrix is chiefly composed of fine quartz grains and sericite. Pyrite is fairly abundant occurring as brecciated fragments scattered throughout the matrix. Other minerals in the matrix which occur only in small amounts, usually in the neighbourhood of pyrite, are brannerite, anatase, rutile, uraninite, monazite, pyrrhotite and galena.

The brannerite occurs in the form of dense aggregates of needle-like crystals, usually about 1/2 mm in cross-section. Brecciated crystals of uraninite are also associated with pyrite in the conglomerate matrix.

Grind

A comparison of the grinds produced by the Mines Branch Abbe laboratory mill and the Stanleigh grinding circuit was made. Screen and infrasizer analyses were done on ore representing the two grinds and the products were assayed for uranium to obtain the distribution of the uranium throughout the sizes (Table 7).

Effect of Desliming on Flotation

In the earlier work (1) it was shown that desliming prior to flotation was beneficial. In order to demonstrate the necessity for the desliming step in the flotation method, the writers carried out two tests at the Stanleigh plant in which one feed sample was deslimed prior to flotation. Later, two tests were carried out at the Mines Branch, following the same procedure, on pulp similar in all ways to the pulp used in the Stanleigh tests. The pulp sample on which this test work was done is designated as Sample A.

The desliming was done by diluting the pulp with Stanleigh plant water in a pail to about 10% solids, and adding 1.0 lb NaOH and 0.5 lb Na_2SiO_3 per ton ore. After conditioning with these reagents for about 5 minutes, the agitation was stopped and the sands allowed to settle for 10 minutes. At the end of the settling period, the top portion containing the slimes was syphoned off. The dilution and settling steps were repeated with no further addition of reagents.

For flotation, Acintol FA-1 was added in stages. The flotation procedure was similar to that described for Test SM-10, page 6, with the exception of the R-610 reagent. In the tests run at the Stanleigh plant, the flotation test in which the slimes were removed, was done at the natural pH of the pulp (about pH 6.5) using cold water (10-12°C) for dilution. The test in which the slimes were not removed was controlled at a pH of 8.2 to 8.5, by the addition of Na_2CO_3, and room temperature water (20-25°C) was used. On both tests run at the Mines Branch in this series, Na_2CO_3 was added to hold the pH during flotation at 8.5 and Stanleigh plant water at room temperature was used. These tests were numbered S-3, S-4, S-5 and S-6 and the results obtained are given in Table 2.

The effect of desliming was investigated further in two tests (SM-3 and SM-5) in which pulp sample B was used (Table 3).

Effect of Type of Water on Flotation

Test work was then done to determine the effect on flotation, of the types of water used in the tests. In these tests pulp sample B was used throughout. The general procedure was to deslime the sample with 1.0 lb/ton of NaOH and 0.5 lb/ton of Na_2SiO_3 as described on page 4 . The sands portion was then treated by flotation, using about 2 lb Acintol FA-1 per ton ore in three stages. In some cases, Cyanamid reagent 610 was used during the float to depress the sericite and certain other silicate minerals.

In order to "soften" the Stanleigh mill water, Na_2CO_3 was added during the desliming step in Test SM-1. In tests SM-9 and SM-10, the Stanleigh mill water was "softened" at the Mines Branch by ion exchange before it was used in the flotation tests. In these tests the grinding water present in the sample was not removed but softened water was used for dilution in the desliming step and in the flotation cell. A single test (SM-7) was done using distilled water for dilution in desliming and flotation.

The procedure used in carrying out the flotation in Test SM-10 is given below. This same general procedure was used in all the flotation tests done in this investigation.

Test SM-10

Softened (ion exchange) Stanleigh mill water used throughout.

Reagents Added	lb/ton
NaOH	1.0
Na_2SiO_3	0.5
Deslimed	
Na_2SiO_3	1.0
Acintol FA-1 (emulsion)	0.75
Conditioned - 3 min (pH 9.1, temp 31°C)	
Rougher Float - 4 min	
Acintol FA-1 (emulsion)	1.0
Conditioned - 3 min (pH 7.8)	
1st Scavenger float - 4 min	
Acintol FA-1 (emulsion)	0.5
Cyanamid R-610	0.5
Conditioned - 3 min	
2nd Scavanger float - 3 min	
Cleaned 2nd Scavenger float	

The results of this test are shown in Table 6.

Laboratory Hydrocyclone Desliming Tests

Test work was done to determine if better results could be obtained by using a desliming technique which is more efficient than the method described on page 4 . It was hoped that more efficient desliming would increase flotation efficiency and at the same time produce a slime fraction of higher uranium grade.

Consequently, a series of four desliming tests was carried out with a laboratory hydrocyclone* by the Non-Ferrous Research Section on samples of the Stanleigh mill ore. The sands from the hydrocyclone operation were floated (SM-11, SM-12) to compare the results with those obtained when the desliming was done by decantation (Table 5).

Particle size analyses were done on two of the hydrocyclone slime products and on one slime product (from Test SM-10) obtained by the conventional decantation method(Table 8).

The first two hydrocyclone tests were run to determine the proper conditions for the operation of the equipment. The third and fourth tests, SM-11 and SM-12, were run with approximately 900 g of sample at an input pressure of 8-9 psig. About 30 litres of overflow was collected in each experiment.

*Purchased from Liquid-Solid Separations Limited, London, England.

Ottawa tap water was used in the hydrocyclone operation. The sands produced were filtered and repulped with softened Stanleigh mill water for the flotation tests.

RESULTS

The results of the flotation test work previously described are given in the following Tables.

Table 2 - Effect of Desliming on Flotation of Sample A.

Table 3 - Effect of Desliming on Flotation of Sample B.

Table 4 - Effect of Water Treatment on Flotation of Sample B.

Table 5 - Effect of Desliming Methods on Flotation of Sample B.

Table 6 - Detailed Results of Test SM-10, Sample B.

In these tests, the preconcentrate for leaching would include the slimes (if the flotation feed was deslimed) plus the rougher float plus the scavenger floats. The number of scavenger floats was usually three. In some tests the second and third scavenger floats were combined and cleaned as in Test SM-10 (Table 6).

TABLE 2

Effect of Desliming on Flotation of Sample A

Test S-3
Without Desliming

Pulp temp. during flotation -20 -25° C
pH - 8.2-8 5 (by Na_2CO_3 addition)
Plant water - Denver Cell
Test run at Stanleigh plant

Products	Wt (%)	U_3O_8 Assay (%)	U_3O_8 Dist. (%)
Slimes	-	-	-
R. Float	3.0	0.17	4.6
1st Scav. Float	2.2	0.28	5.5
2nd Scav. Float	2.8	0.23	5.7
3rd Scav. Float	8.2	0.18	13.2
Scav. Tailings	83.8	0.095	71.0
Head	100.0	0.11	100.0

Test S-4
Deslimed

Pulp temp. during flotation -10 -12° C
pH - about 6.5
Plant water - Denver Cell
Test run at Stanleigh plant

Products	Wt (%)	U_3O_8 Assay (%)	U_3O_8 Dist. (%)
Slimes	2.1	0.14	2.3
R. Float	3.4	0.22	6.1
1st Scav. Float	12.2	0.20	19.7
2nd Scav. Float	23.4	0.25	47.2
—	-	—	-
Scav. Tailings	58.9	0.052	24.7
Head	100.0	0.124	100.0

Test S-5
Without Desliming

Pulp temp. during floation -20 -25° C
pH - 8.5 (by Na_2CO_3 addition)
Plant water - Fagergren Cell
Test run at Mines Branch

Products	Wt (%)	U_3O_8 Assay (%)	U_3O_8 Dist. (%)
Slimes	-	-	-
R. Float	5.55	0.21	10.3
1st Scav. Float	7.51	0.19	12.6
2nd Scav. Float	13.15	0.14	16.2
3rd Scav. Float	9.91	0.23	20.0
Scav. Tailings	63.88	0.073	40.9
Head	100.00	0.11	100.0

Test S-6
Deslimed

Pulp temp. during flotation -20 -25° C
pH - 8.5 (by Na_2CO_3 addition)
Plant water - Fagergren Cell
Test run at Mines Branch

Products	Wt (%)	U_3O_8 Assay (%)	U_3O_8 Dist. (%)
Slimes	27.38	0.14	30.0
R. Float	7.57	0.29	17.2
1st Scav. Float	9.00	0:33	23.3
2nd Scav. Float	9.23	0.16	11.6
—	-	—	—
Scav. Tailings	46.82	0.049	17.9
Head	100.00	0.128	100.0

TABLE 3

Effect of Desliming on Flotation of Sample B
(Flotation conditions were as shown for S-5 and S-6 in Table 2)

Test No.	Preconcentrate Wt (%)	Preconcentrate U_3O_8 Assay (%)	Preconcentrate U_3O_8 Dist. (%)	Number of Scavenger Floats	Remarks
SM-3	59.8	0.13	84.6	3	Deslimed
SM-5	20.3	0.18	36.1	3	Not deslimed

TABLE 4

Effect of Water Treatment on Flotation of Sample B

Test No.	Preconcentrate Wt (%)	Preconcentrate U_3O_8 Assay (%)	Preconcentrate U_3O_8 Dist.	Number of Scavenger Floats	Remarks
SM-1	56.2	0.15	88.7	3	1 lb Na_2CO_3/ton used in desliming
SM-7	61.7	0.15	88.1	3	Distilled water
SM-9	44.6	0.19	85.8	2	Softened water (by ion exchange)
SM-10	45.4	0.22	89.7	2	Softened water (by ion exchange)
SM-3	59.8	0.13	84.6	3	Plant water

TABLE 5

Effect of Desliming Methods on Flotation of Sample B

Test No.	Preconcentrate						Slime Product		
	Desliming Method	Wt (%)	U_3O_8 Assay (%)	U_3O_8 Dist. (%)	Number of Scavenger Floats	Acintol FA-1 lb/ton	Wt (%)	U_3O_8 Assay (%)	U_3O_8 Dist. (%)
SM-9	D*	44.6	0.19	85.8	2	2.0	18.4	0.13	21.5
SM-10	D	45.4	0.22	89.7	2	2.25	20.5	0.13	24.2
SM-11	H*	48.3	0.21	88.4	1	1.75	17.7	0.15	24.2
SM-12	H	45.5	0.18	80.1	3	1.75	17.6	0.16	27.3

* D - Decantation method
H - Hydrocyclone

TABLE 6

Detailed Results of Test SM-10, Sample B

Products	Wt (%)	U_3O_8 Assay (%)	U_3O_8 Dist. (%)
Slimes	20.52	0.13	24.2
Rougher Float	5.66	0.16	8.2
1st Scav. Float	19.22	0.33	57.3
Cleaned 2nd Scav. Float	16.07	0.020	2.9
Cleaned 2nd Scav. Tails	6.59	0.027	1.6
Tails	31.94	0.020	5.8
	100.00	0.11	100.0

Referring to Table 6, if the slimes, rougher float and 1st scavenger float were combined for leaching, the recovery would be 89.7% of the uranium in 45.4% of the weight, at a grade of 0.22 % U_3O_8. In this float 2.25 lb of Acintol was used. However, the 2nd scavenger float was not beneficial and therefore the 0.5 lb of Acintol used here would not be required.

Table 7 gives the results of sizing analyses on the two samples of classifier overflow from the Stanleigh grinding plant. Presented with these results, in the same Table, is the size analysis of a grind produced on a sample of Stanleigh mill feed crushed, in rolls, to minus 10 mesh and ground at the Mines Branch in an Abbe laboratory mill. The test work reported in TB-2 (1) was done using ore ground in the laboratory mill and the size analysis was similar to that shown in Table 7.

TABLE 7

Comparison of Grinds

Size Range	Stanleigh Mill Grinds, Sample A Classifier Overflow: Wt (%)	Sample A: U_3O_8 Assay (%)	Sample A: U_3O_8 Dist. (%)	Stanleigh Mill Grinds, Sample B Classifier Overflow: Wt (%)	Sample B: U_3O_8 Assay (%)	Sample B: U_3O_8 Dist. (%)	Mines Branch Grind (20 min. in Abbe Laboratory Mill): Wt (%)	Mines Branch: U_3O_8 Assay (%)	Mines Branch: U_3O_8 Dist. (%)
+ 48 Mesh	0.6	0.028	0.2	0.2	0.016	0.1	0.5	0.021	0.1
- 48 + 65 Mesh	5.7	0.032	1.7	2.7	0.036	0.9	1.5	0.03	0.5
- 65 + 100 "	7.6	0.039	2.8	9.6	0.037	3.1	9.0	0.065	5.8
-100 + 150 "	17.3	0.060	9.6	13.6	0.054	6.2	22.0	0.11	23.9
-150 + 200 "	9.0	0.096	7.9	9.6	0.071	5.8	13.0	0.10	12.9
-200 M + 56 μ	12.2	0.16	18.0	7.1	0.14	8.4	5.8	0.26	14.9
- 56 + 40 "	11.1	0.12	12.3	12.2	0.11	11.4	11.6	0.084	9.6
- 40 + 28 "	9.0	0.12	9.9	8.9	0.10	7.6	8.9	0.08	7.0
- 28 + 20 "	6.4	0.11	6.4	7.4	0.12	7.6	7.5	0.08	5.9
- 20 + 14 "	4.8	0.11	4.9	6.4	0.12	6.6	5.4	0.082	4.3
- 14 + 10 "	4.0	0.13	4.8	5.5	0.14	6.6	4.2	0.084	3.5
- 10 "	12.3	0.19	21.5	16.8	0.25	35.7	10.6	0.11	11.6
	100.0	0.11	100.0	100.0	0.117	100.0	100.0	0.10	100.0
- 200 Mesh	59.8	0.14	77.8	64.3	0.15	83.9	54.0	0.11	56.8

TABLE 8

Results of Size Analyses of Three Slime Products from Sample B

Size Range microns	SM-11 Hydrocyclone Slimes: Wt (%)	SM-11: U_3O_8 Assay (%)	SM-11: U_3O_8 Dist. (%)	SM-12 Hydrocyclone Slimes: Wt (%)	SM-12: U_3O_8 Assay (%)	SM-12: U_3O_8 Dist. (%)	SM-10 Decanted Slimes: Wt (%)	SM-10: U_3O_8 Assay (%)	SM-10: U_3O_8 Dist. (%)
+ 20 μ							0.6	0.084	0.4
-20 + 14	1.1	0.11	1.0	1.2	0.058	0.6	2.1	0.073	1.4
-14 + 10	1.5	0.091	1.2	1.6	0.14	2.3	4.2	0.077	2.9
-10	15.1	0.16	22.0	14.8	0.17	24.4	13.6	0.16	19.5
Total Slime Fraction	17.7	0.15	24.2	17.6	0.16	27.3	20.5	0.13	24.2
Sands	82.3	0.098	75.8	82.4	0.090	72.7	79.5	0.10	75.8
Heads	100.0	0.11	100.0	100.0	0.10	100.0	100.0	0.11	100.0

Table 8 shows the results of sizing analyses carried out on slime products produced by both hydrocyclone and decantation methods.

Two tests were done in which Tamol 731 and American Cyanamid reagent 601 were used as dispersants and one test was done in which diethyldithiocarbamate was used instead of Acintol FA-1 as a collector. The results of these tests showed that none of these three reagents was beneficial.

DISCUSSION

Since only a limited number of tests was done in this investigation the work can only be considered to be of an exploratory nature.

The results shown in Tables 2 and 3 show that, although in none of these tests was a satisfactory preconcentrate produced, improved results were obtained when the ore was deslimed prior to flotation.

The difference in results between Tests S-3 and S-5, Table 2, could be due to the difference in flotation cells used in the two tests or to aging of the sample in Test S-5. The aging occurred in transporting the sample back to Ottawa. There was a lag of 3 or 4 days between the times of carrying out Tests S-3 and S-5. In Tests S-4 and S-6, not only were there differences in the type of flotation cells used and in the age of the samples, as discussed for Tests S-3 and S-5, but there were also differences in temperature and pulp pH. A comparison of the results of all four tests would indicate that the temperature and pH used in Test S-4 (10-12°C, pH 6.5), did not significantly change the flotation characteristics from those noted at 20-25°C and pH 8.5 as used in the other three tests. However, since it is known that on the Elliot Lake ores the freshly ground ore is flocculated somewhat and settles more rapidly at slightly acid pH values, the pH of 6.5 in Test S-4 may account for the low weight of slimes removed by the decantation method in this test.

Table 4 shows that the use of ion exchange softened water results in a higher ratio of concentration in the flotation concentrate. The differences in uranium recoveries are not thought to be significant.

The results in Table 5 would indicate that more efficient desliming such as effected by the hydrocyclone (see Table 8) does not significantly improve the results obtained in flotation.

The tests which were deslimed by the hydrocyclone are not exactly comparable. In Test SM-11 (Table 5), 0.75 lb Acintol FA-1/ton was added to the rougher float and 1.0 lb FA-1/ton was added to the first scavenger float. This resulted in an excessive weight distribution in the first scavenger concentrate which required two recleaning steps to give the results shown. Because of this, only 0.5 lb FA-1/ton was added to the first scavenger float in Test SM-12 and repeated for two more scavenger floats. The last two scavenger floats were combined and cleaned. This difference in technique resulted in a lower recovery in Test SM-12. These results would indicate that efficient desliming would probably result in reduced collector (FA-1) consumption.

The sizing analyses given in Table 7 shows that in the Stanleigh ground ore up to 35.7% of the contained uranium is in the minus 10 micron fraction. This compares to only 11.6% of the uranium in the minus 10 micron fraction of a laboratory ground product. Since in none of the tests carried out in this investigation were the results as good as those done on laboratory ground products in earlier work (1), the high concentration of uranium in the very fine sizes may be the reason for the poorer flotation results on Stanleigh ground ore.

The results in Table 8 indicate that the hydrocyclone produces a more efficient slime separation than the decantation method. It is interesting that, although the hydrocyclone produces a slime product containing over 85% minus 10 micron material and almost all the 10 micron material in the original ore, the hydrocyclone product does not contain as much uranium as one would expect from the infrasizer analysis in Table 7. It may be that the centrifugal action of the hydrocyclone tends to concentrate the higher density uranium minerals in the coarser fractions to a greater extent than the infrasizer does.

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WRH/dm