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CONCENTRATION OF ILMENITE FROM TITANIFEROUS MAGNETITE ORE FROM LAURENTIAN TITANIUM MINES, LIMITED, WEXFORD TOWNSHIP, QUEBEC

by

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MINERAL PROCESSING DIVISION

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SUMMARY OF RESULTS

The ore assayed:

Soluble iron	-	19.86 %
Titanium dioxide	-	9.48 "
Phosphorus pentoxide	-	1.63 "
Sulphur	-	0.36 "

The ilmenite could be recovered by cobbing the ore at -20M or -65M and concentrating the reground rougher concentrate by the Jones high intensity separator. When cobbing at -20M, the finished -150M ilmenite concentrate assayed 42.87% TiO_2 and the recovery was 31.9%. At -65M the finished -150M ilmenite concentrate assayed 37.54% TiO_2 and the recovery was 49.0%. The P_2O_5 in both concentrates was lower than 0.05%.

The concentrate from flotation assayed TiO_2, 27.72%; P_2O_5, 0.02%; silica, 20.16%. The recovery of TiO_2 was 48.1%. The concentrate was of lower grade on account of the large amount of gangue which did not float. It was also difficult to depress ilmenite.

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INTRODUCTION

Shipments

Three shipments of ore were received at the Mines Branch laboratories in 1960, from Mr. B. C. Salamis, President, Laurentian Titanium Mines Limited, 4462 St. Denis Street, Montreal, Quebec. The first shipment was received on June 3, 1960, weight 250 lb. The ore of this shipment was used for tests in this investigation. An investigation on magnetite concentration from the three shipments of ore received during 1960, was reported in Mines Branch Investigation Report IR 60-78.

Location of the Property

The shipments originated from the property of Laurentian Titanium Mines Limited, in Wexford Township, Terrebonne County, Quebec, about 60 miles northwest of Montreal.

Description of the Property

The property was described in Report IR 60-78, as a titaniferous-magnetite ore body of low grade, estimated at 100 million tons.

Purpose of the Investigation

On January 31, 1962, Mr. Salamis requested that the investigation of the ore in Shipment 1 be continued to determine (1) the recovery and grade of ilmenite concentrate that could be obtained from the non-magnetic tailing after concentrating the magnetite in the ore, and (2), if the ilmenite concentrate would have the specifications required for a commercial grade of titanium concentrate. The specifi-

cations include a low phosphorus content with a maximum of 0.05% P_2O_5.

Sampling and Analysis of Shipment 1

The ore remaining from Shipment 1 was crushed to -20M and a head sample was riffled out for analysis of the feed for the tests.

TABLE 1

Chemical Analysis of the Head Sample of the Remaining Ore of Shipment 1

	%
Total iron	24.06
Soluble iron	19.86
Titanium dioxide	9.48
Silica	30.74
Phosphorus pentoxide	1.63
Sulphur	0.36

No semi-quantitative spectrographic analysis was made on this head sample. A spectrographic analysis of the original head sample of Shipment 1 is shown in Table 2 in Report IR 60-78*. In addition to the above major constituents, tungsten, manganese, vanadium and copper are present in minor or trace amounts.

MINERALOGICAL EXAMINATION

The mineralogy of Shipment 1 was described in Report IR 60-78. It was taken from the Internal Report MS-60-64, by W. E.

*Mines Branch Investigation Report IR 60-78, "Concentration of Titaniferous Magnetite Ore from Laurentian Titanium Mines Limited, Wexford Township, P.Q.", December 13, 1960.

White, Mineral Sciences Division, July 4, 1960.

Ilmenite (and magnetite) are distributed unevenly through the gangue as coarse to fine irregular grains and aggregates. Magnetite and ilmenite are not intimately and finely intergrown and both minerals are largely free of small inclusions of gangue. Gangue minerals are plagioclase and dark pyroxene with minor amounts of apatite, sulphides and garnet as small scattered grains.

Although hematite was not reported in the examination of this shipment, it is intimately associated with the ilmenite in some samples from Shipments 2 and 3. Since complete liberation would be impossible, any ilmenite concentrate would contain some hematite altering the magnetic properties of the mineral and lowering the TiO_2 grade obtainable.

SUMMARY OF PROCEDURE AND RESULTS OF TESTS

After concentrating the ore magnetically to recover magnetite, the tailings were concentrated by gravity and by high intensity magnetic concentration to recover a finished ilmenite concentrate.

The gravity concentrate was reconcentrated by a Stearns high intensity dry separator. In three tests, this concentrate was reground to -150M and concentrated by the Jones high intensity wet separator. In Test 4, flotation was used to concentrate the apatite remaining in -150M ilmenite concentrate from the Stearns separator.

The test procedures and results for the four tests are summarized in Table 2.

TABLE 2

Summary of Tests

	Test 1	Test 2	Test 3	Test 4
Initial grind	-200M	-20M	-65M	-20M
Magnetite concentration	wet drum	dry belt	wet belt	wet belt
Iron conc % Fe	69.12	-	65.26*	44.76
Ilmenite product % TiO_2	10.81	9.83	10.58	8.70
TiO_2 recovery %	95.5	91.5	91.9	76.0
Ilmenite concentration	Wilfley Table	Wilfley Table	Wilfley Table	Deister Table
Ilmenite conc % TiO_2	27.25	19.41	18.97	18.47
TiO_2 recovery %	41.2	73.6	82.7	64.4
Ilmenite cleaning	Jones separator	Stearns (dry belt)	Stearns (dry belt)	Stearns (dry belt)
Ilmenite conc % TiO_2		32.53	30.51	30.86
TiO_2 recovery %		47.9	70.9	54.1
Ilmenite recleaning		Jones separator	Jones separator	Flotation of Apatite
Regrind		-150M	-150M	-150M
Ilmenite conc % TiO_2		40.85	35.79	
% P_2O_5		0.045	0.043	
TiO_2 recovery %		36.5	55.1	
Ilmenite 2nd recleaning		Jones separator	Jones separator	
Final Product				
Assay % TiO_2	38.50	42.87	37.54	27.72
% Fe	31.50	-	-	23.42
% P_2O_5	0.05	0.01	0.03	0.02
% SiO_2	7.70	3.92	6.18	20.16
Recovery TiO_2 %	35.7	31.9	49.0	48.1

*Recleaned on wet drum

DETAILS OF THE TESTS

Test 1 - Recovery of Ilmenite from -200M Ore by High Intensity Magnetic Concentration of Wilfley Table Concentrate

A 2000 g sample of the ore was ground to -200M and concentrated by the Jeffrey-Steffensen separator to recover magnetite.

The Jeffrey-Steffensen tailing was concentrated by gravity on a Wilfley table and the table concentrate was concentrated by the Jones high intensity magnetic separator to recover ilmenite.

TABLE 3

Results of Magnetic Concentration of -200M Ore by the Jeffrey-Steffensen Separator

Product	Weight %	Analysis %		Distn %		R/C
		Fe	TiO_2	Fe	TiO_2	
Feed*	100.0	20.26	9.35	100.0	100.0	
Mag conc	12.6	69.12	0.89	43.1	1.2	7.9:1
Midds	4.8	36.60	6.45	8.6	3.3	
Tailing	82.6	11.84	10.81	48.3	95.5	

*calculated

Additional analyses of the mag conc -

Phosphorus pentoxide - 0.04 %
Sulphur - 0.075 %
Silica - 0.44 %

TABLE 4

Results of Gravity Concentration of the Jeffrey-Steffensen Tailing by the Wilfley Table

Product	Weight %		Analysis %		Distn %				R/C
					In test		In orig feed		
	In test	In orig feed	Fe	TiO_2	Fe	TiO_2	Fe	TiO_2	
Feed*	100.0	82.6	11.84	10.81	100.0	100.0	48.3	95.5	
Table conc	17.1	14.1	25.22	27.25	36.4	43.1	17.6	41.2	7.1:1
Tailing	82.9	68.5	9.08	7.42	63.6	56.9	30.7	54.3	

*calculated

TABLE 5

Results of High Intensity Magnetic Concentration of the Table Concentrate by the Jones Separator

Product	Weight %		Analysis %		Distn %		R/C
					In test	In orig feed	
	In test	In orig feed	TiO_2	P_2O_5	TiO_2	TiO_2	
Feed*	100.0	14.1	24.66	1.16	100.0	41.2	
C1 conc @ 7 amp	55.6	7.8	38.50	0.05	86.7	35.7	12.7:1
C1 midds "	5.7	0.8	15.41	0.30	3.6	1.5	
C1 tailing "	1.9	0.3	9.73	1.11	0.7	0.3	
Rougher conc " *	63.2	8.9	35.56	1.03	91.0	37.5	11.2:1
Rougher midds @ 7 amp	24.1	3.4	7.05	1.92	6.9	2.8	
Rougher tailing @ 7 amp	12.7	1.8	4.06	4.92	2.1	0.9	

*calculated

Additional analyses of the cleaner concentrate -

Iron	-	31.50 %
Sulphur	-	0.17 %
Silica	-	7.70 %
Insoluble	-	18.58 %

Test 2 - Recovery of Ilmenite from -20M Ore by High Intensity Magnetic Concentration of Stearns Concentrate at -150M.

A sample of 6000 g of -20M ore was magnetically concentrated by the Ball-Norton dry belt separator at low intensity to recover magnetite. The tailing was concentrated by gravity on a Wilfley table. The table concentrate was concentrated by a Stearns high intensity dry separator at -20M. The Stearns concentrate was ground by stage grinding to pass 150M. This material was the feed for the Jones high intensity wet separator. Three passes were made of material through the Jones separator. The first pass was made at 0 amp to recover magnetite freed by grinding to -150M. The second pass was made at 7 amp which produced a rougher concentrate, a middling, and a tailing. The rougher concentrate was passed again at 7 amp.

The products were designated as cleaner concentrate, middling and tailing. As the critical element in ilmenite concentrate is phosphorus, the products have been analyzed for TiO_2 and P_2O_5, to show the distribution in Table 9. The analysis of the rougher concentrate was calculated from analyses of the cleaner concentrate, middling and tailing.

It is expected that a maximum of 0.05% P_2O_5 would be allowable in the finished ilmenite concentrate.

TABLE 6

Results of Magnetic Concentration of -20M Ore by the Ball-Norton Separator

Product	Weight %	Analysis %		Distn %		R/C
		TiO_2	P_2O_5	TiO_2	P_2O_5	
Feed*	100.0	8.90	1.52	100.0	100.0	
Mag conc	18.6	4.85	0.69	10.2	8.5	5.4:1
Tailing	81.4	9.83	1.71	89.8	91.5	

*calculated

TABLE 7

Results of Gravity Concentration of the Ball-Norton Tailing by the Wilfley Table at -20M

Product	Weight %		Analysis %		Distn %				R/C
	In test	In orig feed			In test		In orig feed		
			TiO_2	P_2O_5	TiO_2	P_2O_5	TiO_2	P_2O_5	
Feed*	100.0	81.4	9.83	1.71	100.0	100.0	89.8	91.5	
Table conc	41.5	33.7	19.41	0.83	81.9	20.2	73.6	18.5	6.4:1
Tailing	58.5	47.7	3.04	2.33	18.1	79.8	16.2	73.0	

*calculated

Additional Analyses of the Ball-Norton Concentrate -

Iron	-	56.62 %
Sulphur	-	0.29 %
Silica	-	6.08 %
Insoluble	-	15.92 %

TABLE 8

Results of High Intensity Magnetic Concentration of the Wilfley Table Concentrate by the Stearns Dry Separator at -20M

Product	Weight %		Analysis %		Distn %				R/C
					In test		In orig feed		
	In test	In orig feed	TiO_2	P_2O_5	TiO_2	P_2O_5	TiO_2	P_2O_5	
Feed*	100.0	33.7	19.41	0.83	100.0	100.0	73.6	18.5	
Mag conc	38.9	13.1	32.53	0.53	65.1	24.0	47.9	4.4	7.6:1
Midds	39.8	13.4	13.94	0.78	28.6	36.5	21.1	6.7	
Tailing	21.3	7.2	5.71	1.58	6.3	39.5	4.6	7.4	

*calculated

TABLE 9

Results of High Intensity Magnetic Concentration of the Stearns Concentrate by the Jones Separator at -150M

Product	Weight %		Analysis %		Distn %				R/C
					In test		In orig feed		
	In test	In orig feed	TiO_2	P_2O_5	TiO_2	P_2O_5	TiO_2	P_2O_5	
Feed*	100.0	13.11	32.04	0.64	100.0	100.0	47.9	4.42	
Conc @ 0 amp	5.07	0.66	16.20	0.14	2.5	1.1	1.2	0.05	152:1
C1 conc @ 7 amp	49.78	6.53	42.87	0.01	66.6	0.8	31.9	0.04	15.3:1
C1 midds	5.97	0.78	30.51	0.23	5.7	2.2	2.7	0.10	
" tailing	3.95	0.52	31.11	0.20	3.9	1.2	1.9	0.05	
Rougher conc* @ 7 amp	59.70	7.83	40.85	0.045	76.2	4.2	36.5	0.19	12.7:1
Rougher midds	18.76	2.46	18.05	1.52	10.6	44.7	5.1	1.98	
Rougher tailing	16.47	2.16	20.83	1.94	10.7	50.0	5.1	2.20	

*calculated

The Jones cleaner concentrate is the final ilmenite concentrate recovered from the sample of ore. It assayed:

TiO_2 - 42.87 %
P_2O_5 - 0.01 %
S - 0.098 %
Silica - 3.92 %

In terms of the original feed, 31.9% of the TiO_2 in the ore was recovered at a ratio of concentration of 15.3:1. The P_2O_5 was reduced to 0.01%. The rougher concentrate, assaying 40.85% TiO_2 and 0.045% P_2O_5, contains 36.5% of the TiO_2 in the feed at a ratio of concentration of 12.7:1.

Test 3 - Recovery of Ilmenite from -65M Ore by High Intensity Magnetic Concentration of Stearns Concentrate at -150M

A sample of 10 lb of -65M ore was magnetically concentrated by the Crockett wet separator. The Crockett tailing was concentrated by the Wilfley table. The table concentrate was concentrated by the Stearns high intensity dry separator followed by high intensity magnetic concentration of the Stearns concentrate at -150M by the Jones separator.

In this test the -65M Crockett concentrate was cleaned on the Jeffrey-Steffensen separator without regrinding.

TABLE 10

Results of Magnetic Concentration of -65M Ore by the Crockett Separator

Product	Weight %	Analysis %			Distn %			R/C
		Fe	TiO_2	P_2O_5	Fe	TiO_2	P_2O_5	
Feed*	100.0	19.86	9.33	1.53	100.0	100.0	100.0	
Mag conc*	21.6	53.49	3.49	1.27	58.3	8.1	18.0	4.6:1
Tailing*	78.4	10.58	10.94	1.60	41.7	91.9	82.0	

*calculated

TABLE 11

Results of Magnetic Concentration of -65M Crockett Concentrate by the Jeffrey-Steffensen Separator

Product	Weight %		Analysis %			Distn %				R/C
						In test		In orig feed		
	In test	In orig feed	Fe	TiO_2	P_2O_5	Fe	TiO_2	Fe	TiO_2	
Feed*	100.0	21.6	53.49	3.49		100.0	100.0	58.3	8.1	
Mag conc	75.9	16.4	65.26	2.53	0.28	92.6	55.0	54.0	4.5	6.1:1
Midds	9.1	2.0	23.76	6.42	--	4.0	16.7	2.4	1.4	
Tailing	15.0	3.2	11.92	6.60	--	3.4	28.3	1.9	2.2	

*calculated

Additional analyses of the Jeffrey-Steffensen concentrate -

Sulphur - 0.15 %
Silica - 2.16 %
Insoluble - 6.54 %

TABLE 12

Results of Gravity Concentration of the -65M Crockett Tailing by the Wilfley Table

Product	Weight %		Analysis %		Distn %				R/C
					In test		In orig feed		
	In test	In orig feed	TiO_2	P_2O_5	TiO_2	P_2O_5	TiO_2	P_2O_5	
Feed*	100.0	78.4	10.94	1.60	100.0	100.0	91.9	82.0	
Table conc	48.9	38.3	18.97	0.70	89.9	27.5	82.7	22.5	2.6:1
Tailing	51.1	40.1	3.26	2.45	10.1	72.5	9.2	59.5	

*calculated

TABLE 13

Results of High Intensity Magnetic Concentration of the -65M Wilfley Table Concentrate by the Stearns Dry Separator

Product	Weight %		Analysis %		Distn %				R/C
					In test		In orig feed		
	In test	In orig feed	TiO_2	P_2O_5	TiO_2	P_2O_5	TiO_2	P_2O_5	
Feed*	100.0	38.3	18.97	0.70	100.0	100.0	82.7	22.5	
Mag conc	53.4	20.4	30.51	0.97	85.8	73.6	70.9	16.6	4.9:1
Midds	9.6	3.7	17.45	0.45	8.8	6.3	7.3	1.4	
Tailing	37.0	14.2	2.74	0.38	5.4	20.1	4.5	4.5	

*calculated

Additional analyses of the Stearns concentrate and midds:

	Conc	Midds
Iron	25.96%	14.70%
Sulphur	0.21%	-

TABLE 14

Results of High Intensity Magnetic Concentration of the Stearns Concentrate by the Jones Separator at -150M

Product	Weight %		Analysis %		Distn %				R/C
					In test		In orig feed		
	In test	In orig feed	TiO_2	P_2O_5	TiO_2	P_2O_5	TiO_2	P_2O_5	
Feed*	100.0	20.43	29.14	0.28	100.0	100.0	70.9	16.6	
Conc @ 0 amp	2.8	0.57	36.29	0.26	3.5	2.6	2.5	0.5	175:1
C1 conc 7 amp	53.7	10.96	37.54	0.03	69.1	5.7	49.0	0.9	9.1:1
C1 midds "	6.2	1.26	27.06	0.09	5.7	1.9	4.1	0.3	
C1 tailing "	3.4	0.69	24.06	0.17	2.8	2.1	2.0	0.4	
Rougher conc* @ 7 amp	63.3	12.91	35.79	0.043	77.6	9.7	55.1	1.6	7.75:1
Rougher midds	19.0	3.90	15.59	0.56	10.2	37.5	7.2	6.2	
" tailing	14.9	3.05	16.98	0.96	8.7	50.2	6.1	8.3	

*calculated

Additional analyses of the Jones cleaner concentrate -

Sulphur - 0.080 %
Silica - 6.18 %

The results of this test indicated that the cleaner ilmenite concentrate contained 49.0% of the TiO_2 in the original feed, at a ratio of concentration of 9.1:1.

The rougher ilmenite concentrate assayed 0.043% P_2O_5 by calculation, with a recovery of 55.1% of the TiO_2 in the feed at a ratio of concentration of 7.75:1.

The amount of P_2O_5 in the ilmenite concentrate for commercial use is said to be limited to 0.05%.

Test 4 - Recovery of Ilmenite from -20M Ore,
Flotation of Apatite from the Ilmenite Concentrate at -150M

A sample of 10 lb of -20M ore was magnetically concentrated by the Crockett wet separator. The Crockett tailing was concentrated by gravity on a Deister table. The Deister table concentrate was concentrated by the Stearns high intensity dry separator. The Stearns separator rejected some apatite free of magnetic particles at -20M. The apatite was freed from locked grains by grinding the Stearns concentrate to -150M and was eliminated by flotation. In this test the flotation tailing is the ilmenite concentrate.

The concentrate, ground to -150M was conditioned in a flotation machine for 5 minutes with soda ash at the rate of 3 lb/ton of feed, pH of pulp 10.2. Hardesty No. 4 oleic acid was used as a collector for apatite and was stage fed; 3/4 lb/ton was used in the test. No frother was used. The rougher float was cleaned twice with an addition of 0.05 lb/ton of oleic acid to each cleaner stage, but no acceptable product was obtained.

A microscopic examination of the ilmenite concentrate showed a considerable amount of gangue minerals to be present.

TABLE 15

Results of Magnetic Concentration of -20M Ore by the Crockett Separator

Product	Weight %	Analysis %		Distn %		R/C
		Fe	TiO_2	Fe	TiO_2	
Feed*	100.0	18.95	9.04	100.0	100.0	
Mag conc	28.4	44.76	6.52	67.1	20.5	3.5:1
Sands tailing	67.0	8.70	10.26	30.7	76.0	
Slime tailing	4.6	8.96	6.78	2.2	3.5	

*calculated

TABLE 16

Results of Gravity Concentration of the Crockett Sand Tailing by the Deister Table

Product	Weight %		Analysis %		Distn %				R/C
	In test	In orig feed	Fe	TiO_2	In test		In orig feed		
					Fe	TiO_2	Fe	TiO_2	
Feed*	100.0	67.0	9.86	9.93	100.0	100.0	30.7	76.0	
Table conc	40.0	26.8	18.47	18.47	74.9	84.7	23.0	64.4	3.7:1
Tailing	60.0	40.2	4.12	2.53	25.1	15.3	7.7	11.6	

*calculated

TABLE 17

Results of High Intensity Magnetic Concentration of the Deister Table Concentrate by the Stearns Dry Separator

Product	Weight %		Analysis %		Distn %				R/C
					In test		In orig feed		
	In test	In orig feed	Fe	TiO_2	Fe	TiO_2	Fe	TiO_2	
Feed*	100.0	26.8	18.47	21.03	100.0	100.0	23.0	64.4	
Mag conc	57.3	15.3	25.96	30.86	80.5	84.0	18.5	54.1	6.5:1
Midds	20.8	5.6	8.50	8.26	9.6	8.2	2.2	5.3	
Tailing	21.9	5.9	8.36	7.50	9.9	7.8	2.3	5.0	

*calculated

TABLE 18

Results of Flotation of Apatite from the Stearns Concentrate

Product	Weight %		Analysis %		Distn %			R/C
					In test		In orig feed	
	In test	In orig feed	TiO_2	P_2O_5	TiO_2	P_2O_5	TiO_2	
Feed*	100.0	15.3	30.76	0.56	100.0	100.0	54.1	
Apatite float	16.0	2.5	33.33	3.07	17.6	87.2	9.5	41:1
C1 tailing 1	21.3	3.3	34.22	0.16	24.2	5.8	13.1	
C1 " 2	8.8	1.3	35.12	0.29	10.1	4.7	5.4	
Rougher tailing ilmenite conc	53.4	8.2	27.72	0.02	48.1	2.3	26.1	12.2:1
Rougher concentrate*	46.6	7.1	34.26	1.18	51.9	97.7	28.0	14:1

*calculated

Additional analyses of ilmenite concentrate -

Iron - 23.42 %
Sulphur - 0.23 %
Silica - 20.16 %

In this test, the rougher flotation tailing is the ilmenite concentrate.

CONCLUSIONS

The results indicated that grinding to -65M was best for magnetite concentration and rougher concentration of the ilmenite by gravity (Test 3).

Grinding of the rougher ilmenite concentrate to -150M was necessary to liberate the apatite. At this grind the Jones high intensity wet magnetic separator produced acceptable ilmenite concentrates with less than 0.05% P_2O_5.

Although dry high intensity (Stearns) treatment reduced the tonnage to the Jones separator, the cost of drying would make this step uneconomic.

Apatite flotation successfully reduced the P_2O_5 content to less than 0.05% P_2O_5 but the resulting concentrate contained too much gangue mineral.

ACKNOWLEDGEMENTS

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WSJ:EBM