GEOLOGICAL SURVEY OF CANADA

OPEN FILE 2209

INDUSTRIAL MINERALS IN EASTERN ONTARIO: SILLIMANITE RECOVERY FOR CLARENDON AND OTTER CREEK SITES

Lakefield Research

1990

Energy, Mines and Resources Canada
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Inside Front Cover

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Energy, Mines and Resources Canada

Énergie, Mines et Ressources Canada

An Investigation of

THE RECOVERY OF SILLIMANITE, GARNET & MICA

from samples of Clarendon and Otter Creek ore

submitted by

S.J.B. GEOLOGY SERVICES

Progress Report No. 1

Project No. L.R. 3434

NOTE:

This report refers to the samples as received.

LAKEFIELD RESEARCH
A DIVISION OF FALCONBRIDGE LIMITED
May 6, 1988

PREFACE

This report contains the results of a beneficiation study done by Lakefield Research on rock samples from two sites in Eastern Ontario. These sites have been geologically characterized in Open File reports, particularily with respect to their sillimanite potential. The Open File reports are:

Black, S. J. and A. N. Rencz. 1988.
Industrial minerals in Eastern Ontario: Clarendon sillimanite occurrence. GSC Open File # 1672, 14 p.

Black S. J. 1989.
Industrial minerals in Eastern Ontario: Otter Creek sillimanite occurrence. GSC Open File # 2095, 8 p.

The report from Lakefield Research is published with no changes and with the consent of the company.

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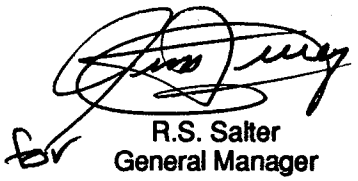
INTRODUCTION

On December 7, 1987, Mr. Stephen J. Black in association with the Canada-Ontario MDA requested that a test program be completed on two Sillimanite-Garnet ores from Southern Ontario.

The testwork was discussed with Mr. Black as the program proceeded.

LAKEFIELD RESEARCH



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SUMMARY AND CONCLUSIONS

1. Head Samples

The two ore samples received were designated Clarendon and Otter Creek. Estimates of the composition of these products as determined from the testwork are given in Table No. 1.

TABLE NO. 1 : Head Composition

	% Composition				
	Sillimanite	Garnet	Quartz	Mica	Magnetite
Clarendon	24.6	5.6	22.6	46.0	1.6
Otter Creek	21.9	5.4	18.6	52.0	2.1

The samples are from a pelitic gneiss containing biotite, quartz and sillimanite as the major constituents with garnet, muscovite and magnetite being minor constituents.

2. Clarendon Testwork

2.1. Gravity Testwork

Two kilograms of ground minus 30 mesh (17 % minus 200 mesh) Clarendon sample was screened at 100 and 400 mesh. The plus 100 mesh and 400 mesh fractions were tabled on a 1/8 Wilfley table to produce gravity products while the minus 400 mesh was rejected as slimes. Figure 1 illustrates the flowsheet. Table No. 2 indicates the material balance obtained from the gravity separation. On an individual basis, gravity separation would not produce a high grade product of either sillimanite or garnet but could be used as a pre-concentrating step.

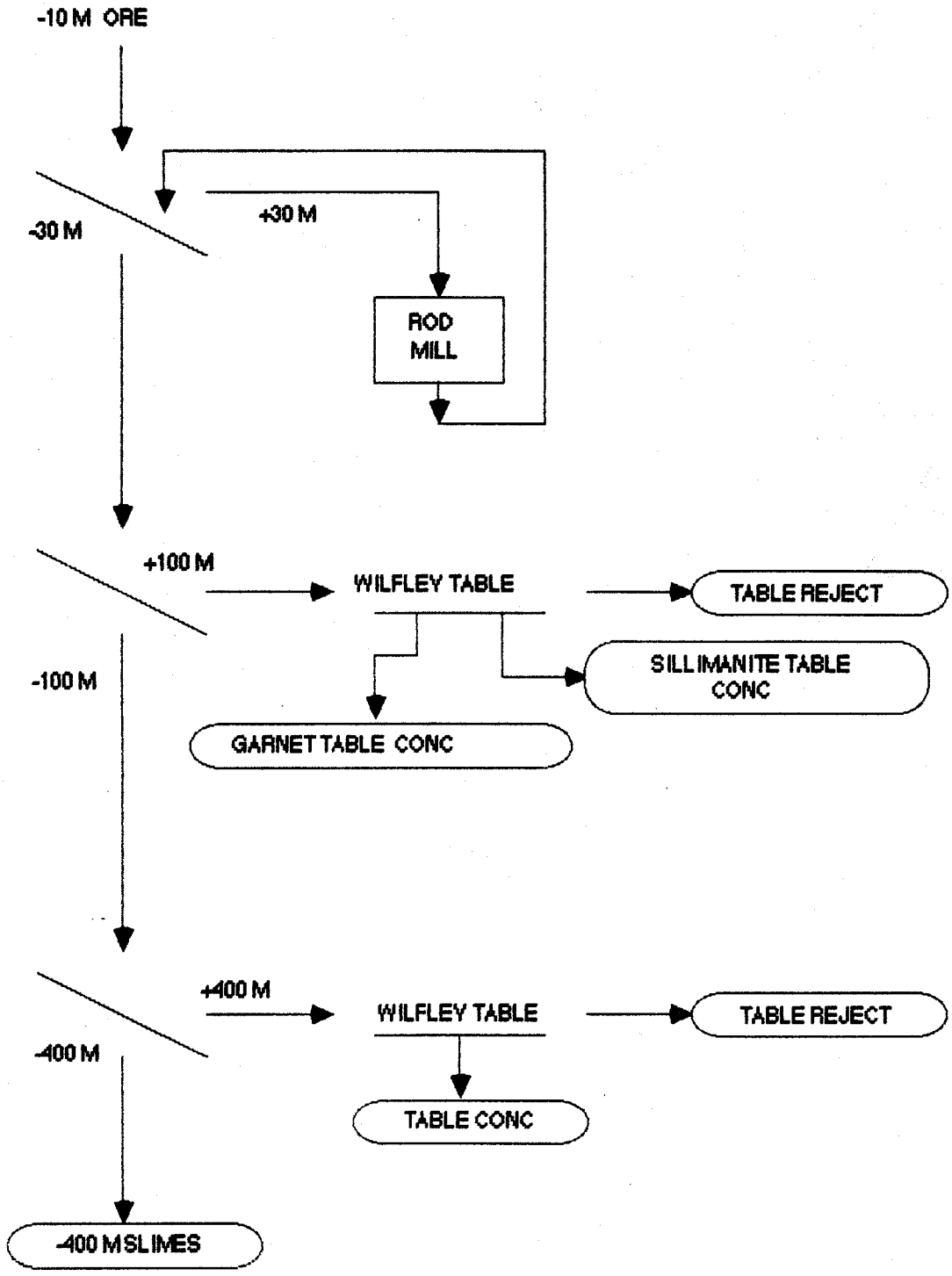
Table No. 2 : Gravity Results

Product	Weight %	Assays %*					% Distribution*				
		Bio	Quartz	Sillim	Garn	Magn	Bio	Quartz	Sillim	Garn	Magn
-30+100 Table Reject	18.64	80.0	10.0	10.0	0.0	0.0	32.8	7.9	7.6	0.0	0.0
-30+100 Garnet Conc	10.13	25.0	20.0	15.0	30.0	10.0	5.6	8.6	6.2	66.0	59.9
-30+100 Sillimanite Conc	46.93	40.0	25.0	33.0	2.0	0.0	41.3	49.5	63.2	20.4	0.0
-100+400 Table Reject	4.97	85.0	5.0	10.0	0.0	0.0	9.3	1.0	2.0	0.0	0.0
-100+400 Table Conc	11.30	27.0	55.0	10.0	2.0	6.0	6.7	26.2	4.6	4.9	40.1
-400 Slimes	8.02	25.0	20.0	50.0	5.0	0.0	4.4	6.8	16.4	8.7	0.0
Head (Calc)	100.00	45.5	23.7	24.5	4.6	1.7	100.0	100.0	100.0	100.0	100.0

*Biotite / Quartz / Sillimanite / Garnet / Magnetite

The level of pre-concentration achieved with gravity was not optimized in this phase of testwork.

Figure No. 1 - Gravity Test Flowsheet



2.2. Magnetic Separation

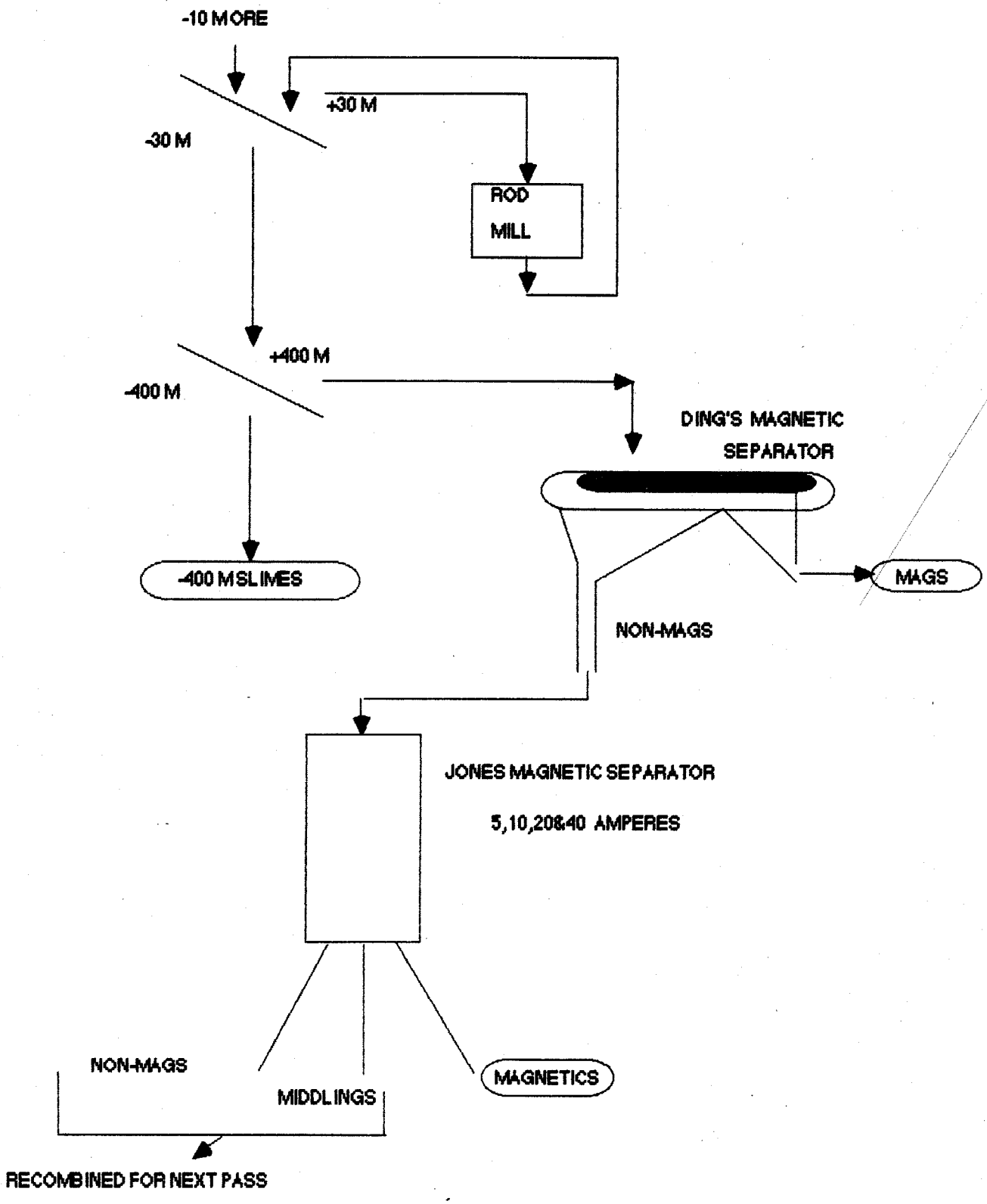
A one kilogram sample of -30 mesh Clarendon sample (17 % -200 mesh) was treated with the Dings Magnetic Separator and the Jones Magnetic Separator to obtain a sequential separation at increasing magnetic field strength (gauss levels). Figure No. 2 illustrates the flowsheet used. Table No. 3 indicates the material balance obtained from the testwork. Mica and sillimanite were distributed in significant quantities into each product. The garnet was separated at the two lowest levels of field strength (guass intensities) on the Jones but the presence of sillimanite suggests an incomplete liberation of the garnet from the sillimanite.

TABLE NO. 3 : Magnetic Separation Results

Product	Weight %	Assays %*					% Distribution*				
		Mica	Quartz	Sillim	Garn	Magn	Mica	Quartz	Sillim	Garn	Magn
Dings Magnetic Conc	4.09	30.0	15.0	20.0	0.0	35.0	2.8	2.9	3.0	0.0	90.8
Jones 5amp Mag Conc	10.63	32.0	8.0	30.0	30.0	0.0	7.8	4.1	11.6	50.3	0.0
Jones10amp Mag Conc	15.27	70.0	2.0	14.0	14.0	0.0	24.5	1.5	7.7	33.7	0.0
Jones 20amp Mag Conc	8.22	77.0	5.0	13.0	5.0	0.0	14.5	2.0	3.9	6.5	0.0
Jones 40amp Mag Conc	3.07	67.0	12.0	20.0	1.0	0.0	4.7	1.8	2.2	0.5	0.0
Jones 40amp Midds	6.33	47.0	20.0	33.0	0.0	0.0	6.8	6.1	7.6	0.0	0.0
Jones 40amp Non-mags	43.30	30.0	35.0	35.0	0.0	0.0	29.8	72.6	55.0	0.0	0.0
-400 Slimes	9.09	43.6	20.9	27.6	6.3	1.6	9.1	9.1	9.1	9.0	9.2
Head (Calc)	100.00	43.6	20.9	27.6	6.3	1.6	100.0	100.0	100.0	100.0	100.0

*Mica / Quartz / Sillimanite / Garnet / Magnetite

Figure No. 2 - Magnetic Separation Flowsheet



2.3. Flotation Testwork

One flotation test was completed on the Clarendon ore. A finer grind at 23 % -200 mesh was used. One kilogram of ground slurry (-30 mesh) was deslimed at 270 mesh. The plus 270 mesh was attritioned scrubbed and conditioned at 50 % solids with sodium silicate (Na_2SiO_3) and sodium carbonate (Na_2CO_3). Mica was floated using Armac T (cationic tallow amine) at pH 10.2. After a dose of 250 g/t the float became nonselective and gangue was floated. No selectivity could be obtained in the cleaning stages on the mica rougher concentrate.

A fatty acid (Pamak C4) was used to float sillimanite from the mica rougher tail but nothing would float. This step was re-named a mica scavenger. Another fatty acid Pamak 4 was used but was unsuccessful in pulling significant quantities of sillimanite. Figure 3 illustrates the flowsheet used.

Table 4 summarizes the mineral composition of the products obtained during flotation.

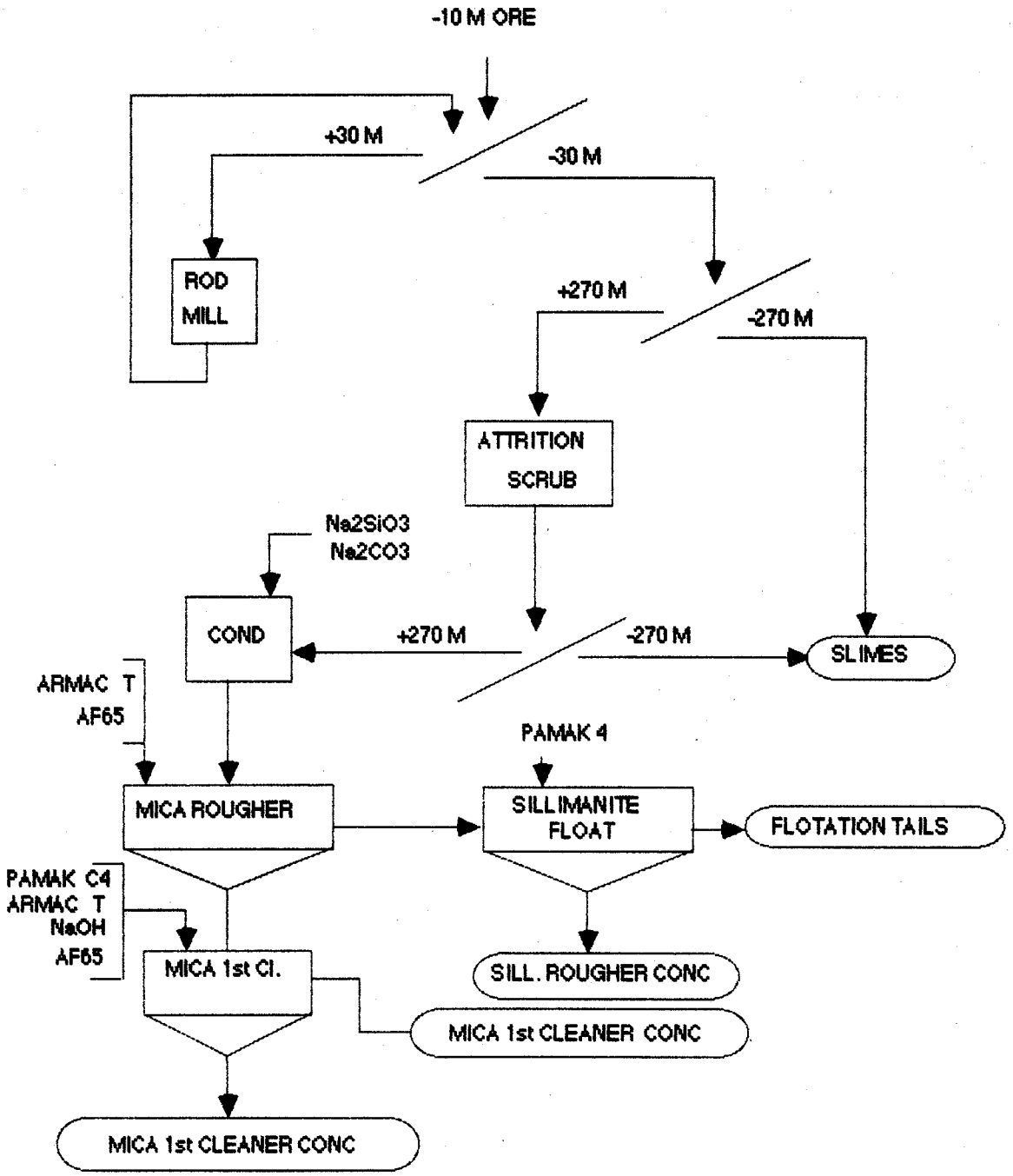
TABLE NO. 4 : Flotation Results, Clarendon Ore

Product	Weight %	Assays %*					% Distribution*				
		Mica	Quartz	Sillim	Garn	Magn	Mica	Quartz	Sillim	Garn	Magn
Mica 1st Cleaner Conc	28.51	84.0	15.0	0.0	0.0	1.0	49.1	18.4	0.0	0.0	18.1
Sillimanite 1st Rougher Conc	2.15	80.0	12.0	5.0	2.0	1.0	3.5	1.1	0.5	0.7	1.4
Sillimanite 2nd Rougher Conc	6.11	70.0	10.0	18.0	1.0	1.0	8.8	2.6	5.1	1.0	3.9
Flotation Tails	50.49	25.0	30.0	35.0	10.0	2.0	25.9	65.1	81.7	85.5	64.0
-270 Slimes	12.73	48.8	23.3	21.6	5.9	1.6	12.7	12.7	12.7	12.7	12.7
Head (Calc)	100.00	48.8	23.3	21.6	5.9	1.6	100.0	100.0	100.0	100.0	100.0

*Mica / Quartz / Sillimanite / Garnet / Magnetite

The inability to remove mica from the other minerals during this single test indicates that the conditions were not optimal and that additional scoping flotation work is required.

Figure No.. 3 - Flotation Testwork



3. Otter Creek Testwork

3.1. Flotation Testwork

Due to the similarity of the ore and in an attempt to float more of the coarse mica, the basic cationic flotation of mica was replaced with the acid cationic procedure. A grind of 20 % -200 mesh was utilized with desliming at 270 mesh. The thickened slurry was conditioned with sulphuric acid to pH 4.0 for three minutes. A second conditioning stage with Armac T was carried out for 3 minutes prior to rougher flotation. Fine mica floated easily while coarse mica would only float with gangue. Cleaning stages for mica were not very selective at this point. Sillimanite flotation with Pamak C4 was poor with the majority of the sillimanite remaining in the flotation tailing.

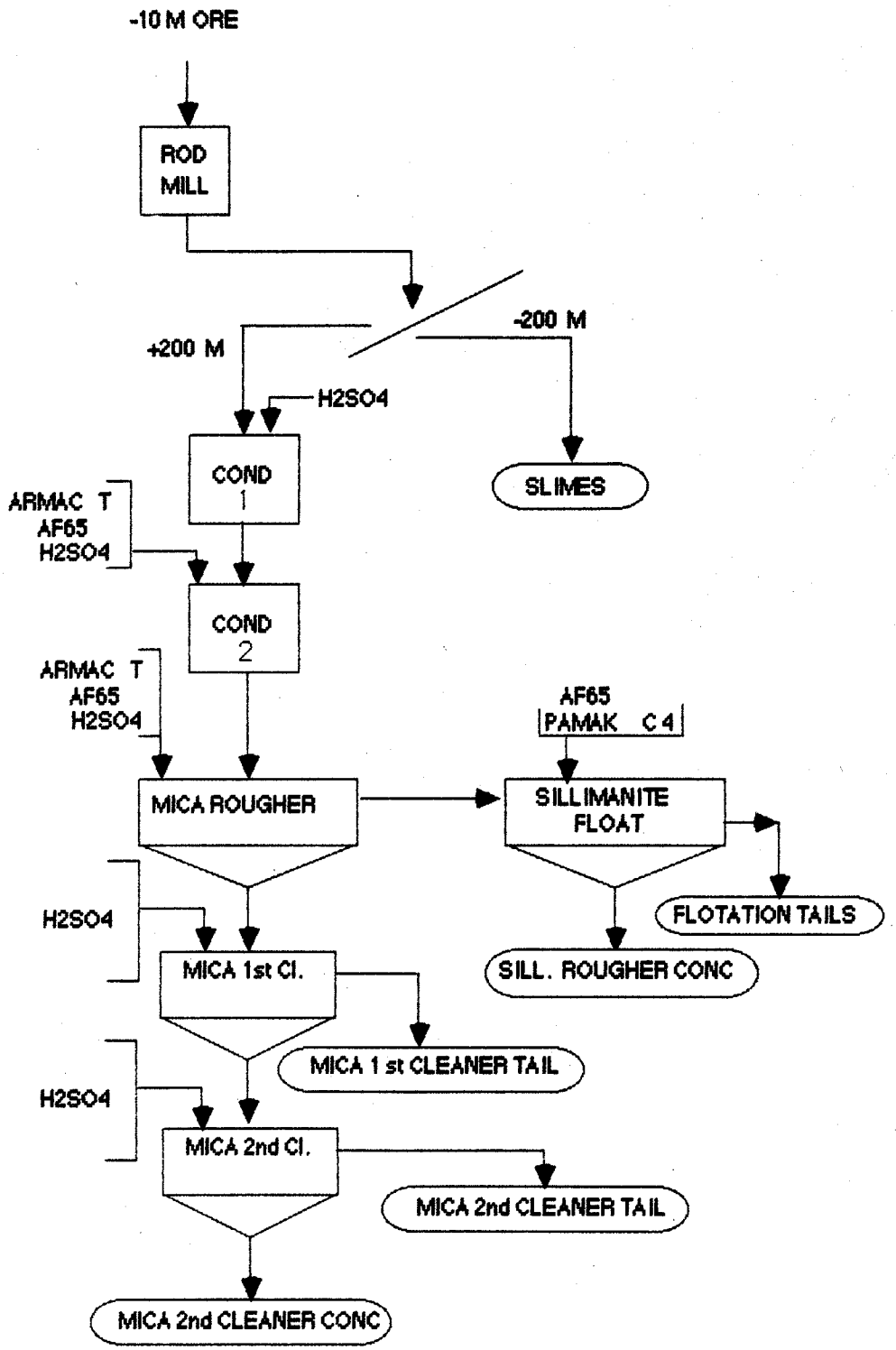
Figure No. 4 illustrates the flowsheet used while Table 5 displays the mineral composition of the products obtained during flotation.

TABLE NO. 5 : Flotation Results, Otter Creek

Product	Weight %	Assays %*					% Distribution*				
		Mica	Quartz	Sillim	Garn	Magn	Mica	Quartz	Sillim	Garn	Magn
Mica 2nd Cleaner Conc	27.86	75.0	12.0	8.0	3.0	2.0	40.1	18.0	10.2	15.6	26.9
Mica 2nd Cleaner Tails	9.04	60.0	25.0	12.0	1.0	2.0	10.4	12.2	4.9	1.7	8.7
Mica 1st Cleaner Tails	6.77	54.0	25.0	16.0	2.0	3.0	7.0	9.1	4.9	2.5	9.8
Sillimanite Rougher Conc	0.77	28.0	38.0	20.0	12.0	2.0	0.4	1.6	0.7	1.7	0.7
Flotation Tails	46.95	37.0	20.0	33.0	8.0	2.0	33.4	50.5	70.6	69.9	45.3
-270 Slimes	8.61	52.0	18.6	21.9	5.4	2.1	8.6	8.6	8.6	8.6	8.6
Head (Calc)	100.00	52.0	18.6	21.9	5.4	2.1	100.0	100.0	100.0	100.0	100.0

*Mica / Quartz / Sillimanite / Garnet / Magnetite

Figure No. 4- Otter Creek Flotation



RECOMMENDATIONS

Based on the preliminary testwork completed, the following additional work is recommended:

1. Based on the similarity in mineral composition and response of the two ores, future development testwork maybe simplified to only one ore sample or a composite sample.

2. Methods of liberating the majority of the mica from the sillimanite/garnet nodules at a coarse size should be investigated.

3. A mica rejection step using flotation should be optimized prior to sillimanite and garnet concentration.

SAMPLE PREPARATION

On December 14, 1987, Mr. S.J. Black delivered two samples of rock identified as Otter Creek and Clarendon. The samples were given the Lakefield designation number LR 8728748.

Each rock type was crushed to -10 mesh and riffled. Representative one kilogram charges were made out of all the material.

DETAILS OF TESTS

TEST NO. CL-1

Purpose: To conduct a preliminary investigation into the separation of garnet and sillimanite from the biotite host mineral using tabling techniques.

Procedure: A 2 kg (-10 mesh) sample was screened through a 30 mesh screen. The +30 mesh fraction was then ground in a 2 kg rod mill for 5 minutes. The ground material was then screened again through 30 mesh and the +30 mesh was reground for an additional 2.5 minutes. After screening again, the left over +30 mesh fraction (wgt = approx. 25 g) was filtered while the -30 mesh fraction was passed through 100 mesh. The -100 mesh product was then deslimed at 400 mesh while the +100 mesh fraction was separated into a garnet table concentrate. Sillimanite table concentrate and a table reject using the I/8 Wilfley table. The +400 mesh fraction was also tabled into Reject and Table concentrate products while the -400 mesh slimes were filtered and saved.

Feed: 2 kg of -10 mesh Clarendon ore.

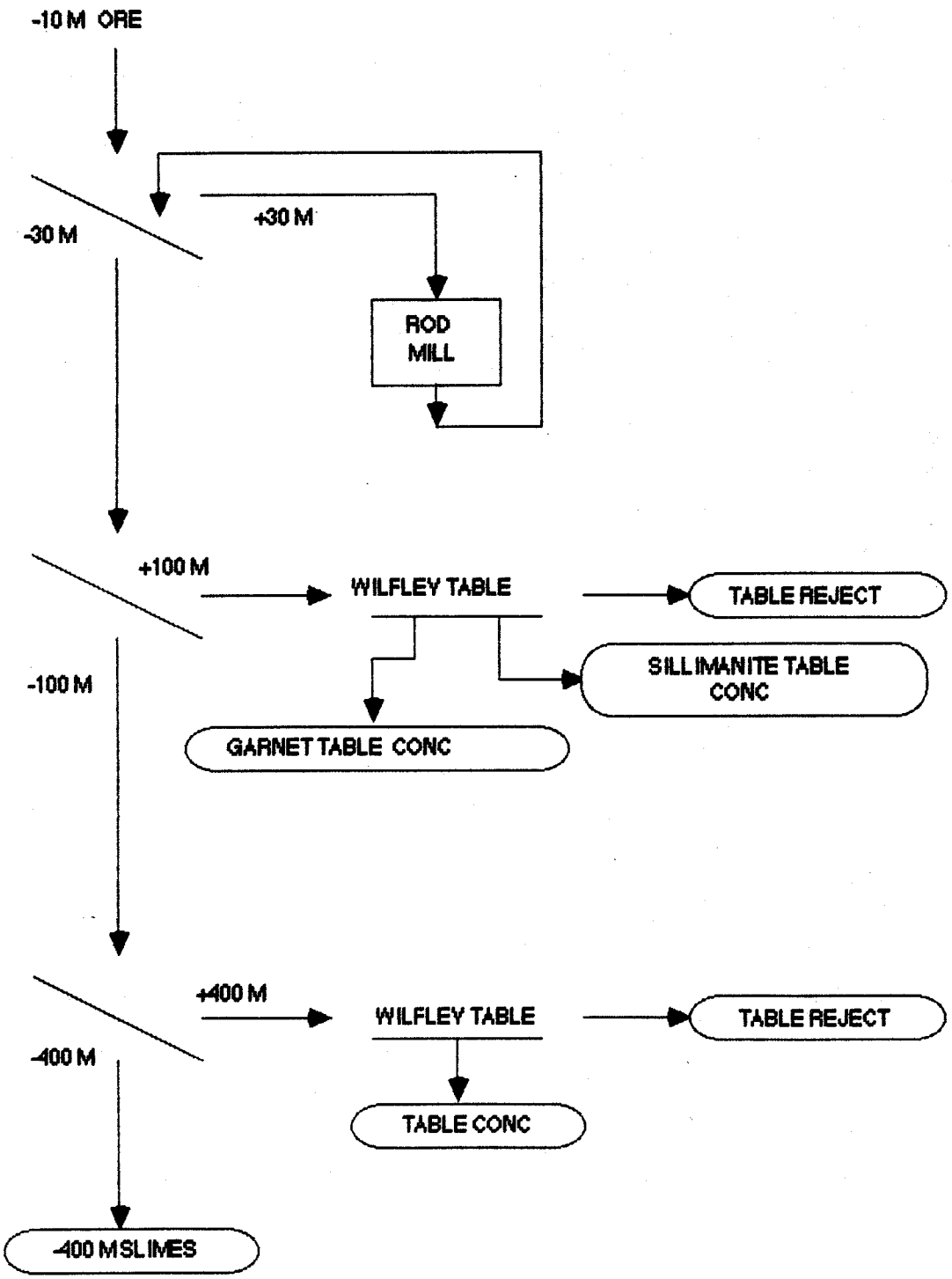
Grind: 5 minute/2 kg feed using the +30 mesh fraction ground in 2 kg rod mill at 50 % solids.

Test No. CL1

Product	Wt %	Assay % Biotite	Quartz	Sillimanite	Garnet	Magnetite
-30+100 Table Reject	18.64	80.0	10.0	10.0	0.0	0.0
-30+100 Garnet Conc	10.13	25.0	20.0	15.0	30.0	10.0
-30+100 Sillimanite Conc	46.93	40.0	25.0	33.0	2.0	0.0
-100+400 Table Reject	4.97	85.0	5.0	10.0	0.0	0.0
-100+400 Table Conc	11.30	27.0	55.0	10.0	2.0	6.0
-400 Slimes	8.02	25.0	20.0	50.0	5.0	0.0
Head(calc)	100.00	45.5	23.7	24.5	4.6	1.7

	% Distribution Biotite	Quartz	Sillimanite	Garnet	Magnetite
-30+100 Table Reject	32.8	7.9	7.6	0.0	0.0
-30+100 Garnet Conc	5.6	8.6	6.2	66.0	59.9
-30+100 Sillimanite Conc	41.3	49.5	63.2	20.4	0.0
-100+400 Table Reject	9.3	1.0	2.0	0.0	0.0
-100+400 Table Conc	6.7	26.2	4.6	4.9	40.1
-400 Slimes	4.4	6.8	16.4	8.7	0.0
Head(calc)	100.0	100.0	100.0	100.0	100.0

TEST No. CL1 FLOWSHEET



Test No. CI-1 - Continued

Screen Analysis

Combined Product

Mesh Size (Tyler)	% Retained		% Passing Cumulative
	Individual	Cumulative	
+ 28	3.2	3.2	96.8
35	16.2	19.4	80.6
48	21.2	40.6	59.4
65	15.4	56.0	44.0
100	12.0	68.0	32.0
150	8.8	76.8	23.2
200	6.2	83.0	17.0
270	4.1	87.1	12.9
400	2.4	89.5	10.5
- 400	10.5	100.0	-
Total	100.0	-	-

TEST NO. CL-2

Purpose: To investigate the effect of magnetic separation techniques on the distribution of sillimanite and garnet.

Procedure: The ground ore (-30 mesh) was deslimed on 400 mesh and passed through the Dings Permanent Magnetic Separator. The Dings non-magnetic passed through the Jones Magnetic Separator to produce a 5 amp Mag and Non-mag product. The Non-mags were repassed repeatedly at various amperages, 10, 20 and 40 amps to produce a 40 amp non-mag product. All products were submitted for mineralogical evaluation.

Feed: 1 kg of -10 mesh Clarendon ore.

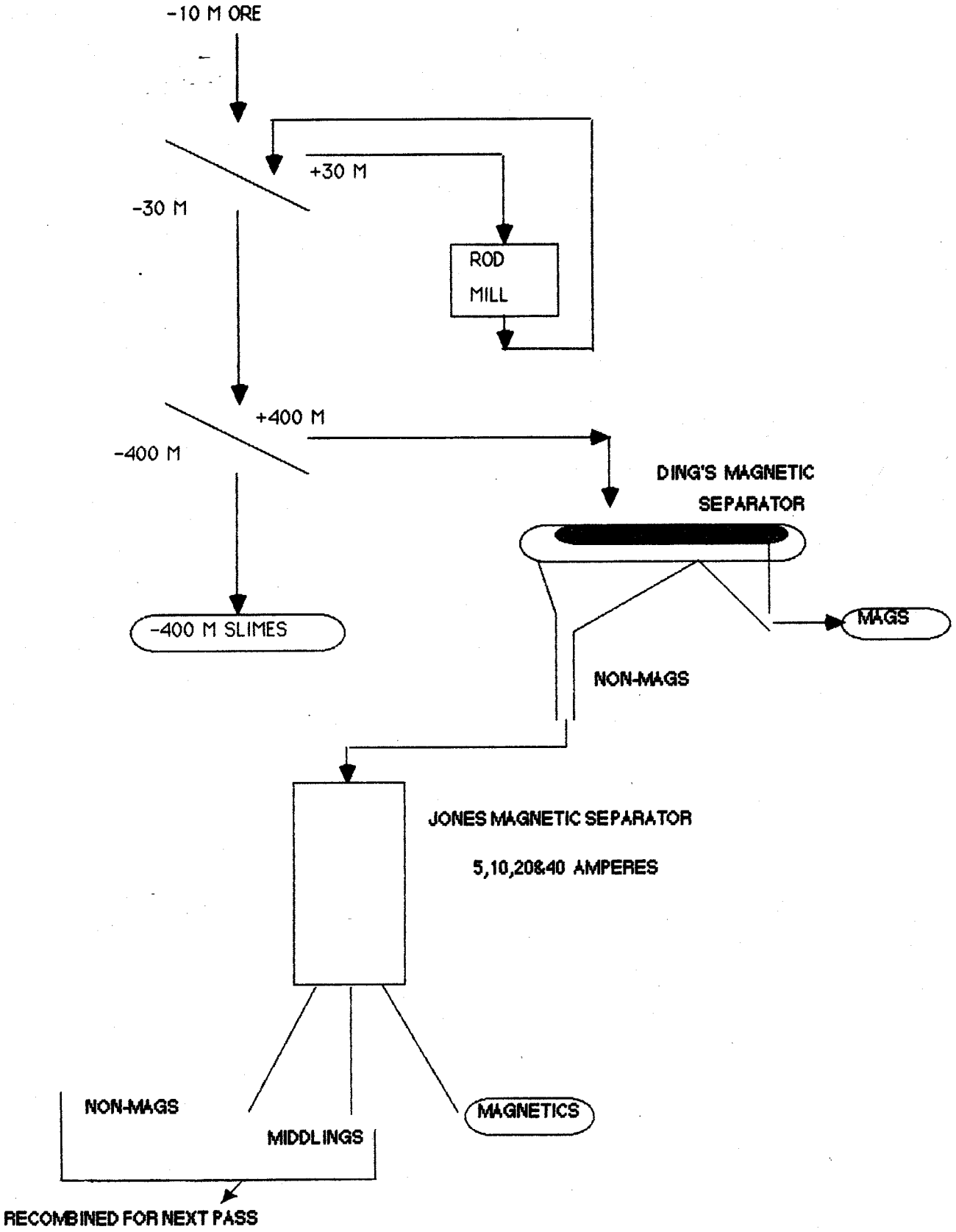
Grind: As outlined in Table CL-1.

Test No. CL2

Product	Wt %	Assay % Mica	Quartz	Sillimanite	Garnet	Magnetite
Dings Mag Conc	4.09	30.0	15.0	20.0	0.0	35.0
Jones 5amp Mag Conc	10.63	32.0	8.0	30.0	30.0	0.0
Jones 10amp Mag Conc	15.27	70.0	2.0	14.0	14.0	0.0
Jones 20amp Mag Conc	8.22	77.0	5.0	13.0	5.0	0.0
Jones 40amp Mag Conc	3.07	67.0	12.0	20.0	1.0	0.0
Jones 40amp Midds	6.33	47.0	20.0	33.0	0.0	0.0
Jones 40amp Non-Mags	43.30	30.0	35.0	35.0	0.0	0.0
-400 Slimes	9.09	43.6	20.9	27.6	6.3	1.6
Head(calc)	100.00	43.6	20.9	27.6	6.3	1.6

	% Distribution Mica	Quartz	Sillimanite	Garnet	Magnetite
Dings Mag Conc	2.8	2.9	3.0	0.0	90.8
Jones 5amp Mag Conc	7.8	4.1	11.6	50.3	0.0
Jones 10amp Mag Conc	24.5	1.5	7.7	33.7	0.0
Jones 20amp Mag Conc	14.5	2.0	3.9	6.5	0.0
Jones 40amp Mag Conc	4.7	1.8	2.2	0.5	0.0
Jones 40amp Midds	6.8	6.1	7.6	0.0	0.0
Jones 40amp Non-Mags	29.8	72.6	55.0	0.0	0.0
-400 Slimes	9.1	9.1	9.1	9.0	9.2
Head(calc)	100.0	100.0	100.0	100.0	100.0

TEST No. CL2 FLOWSHEET



TEST NO. CL-3

Purpose: To conduct a preliminary flotation separation of garnet and sillimanite from the biotite host rock.

Procedure: As indicated below.

Feed: 1 kg -10 mesh Clarendon ore.

Grind: 4 min/kg original feed wgt, using the +30 mesh fraction.

Conditions:

Stage	Reagents Added, grams per tonne							Time, minutes			pH
	Na_2SiO_3	Na_2CO_3	NaOH	Armac T	Pamak C4	FA 65	Pamak 4	Grind	Cond.	Froth	
Screen on 30 mesh											
Grind +30 mesh								4			-
Screen on 270 mesh											
Attrition scrub									2		
Screen on 270 mesh											
Mica Cond	500	500	-	-	-	-	-	-	3	-	10.2
Mica Rougher	-	-	-	150	-	70	-	-	2	3	10.0
	-	-	-	100	-	-	-	-	1	2	9.7
	-	-	-	100	-	41	-	-	1	4	9.6
Mica Cleaner	-	-	-	50	-	-	-	-	1	4	-
	-	-	40	-	60	21	-	-	4	-	-
	-	-	60	-	480	-	-	-	2	-	-
(Mica Cl Tail is called 1st Sillimanite Rougher Conc)											
Sillimanite Float (conducted on Mica Ro Tail)						100	-	-	-	-	-
Sillimanite Float Conc is called 2nd Sillimanite Rougher Conc)											

Biotite causing problems with flotation of Sillimanite. Poor float

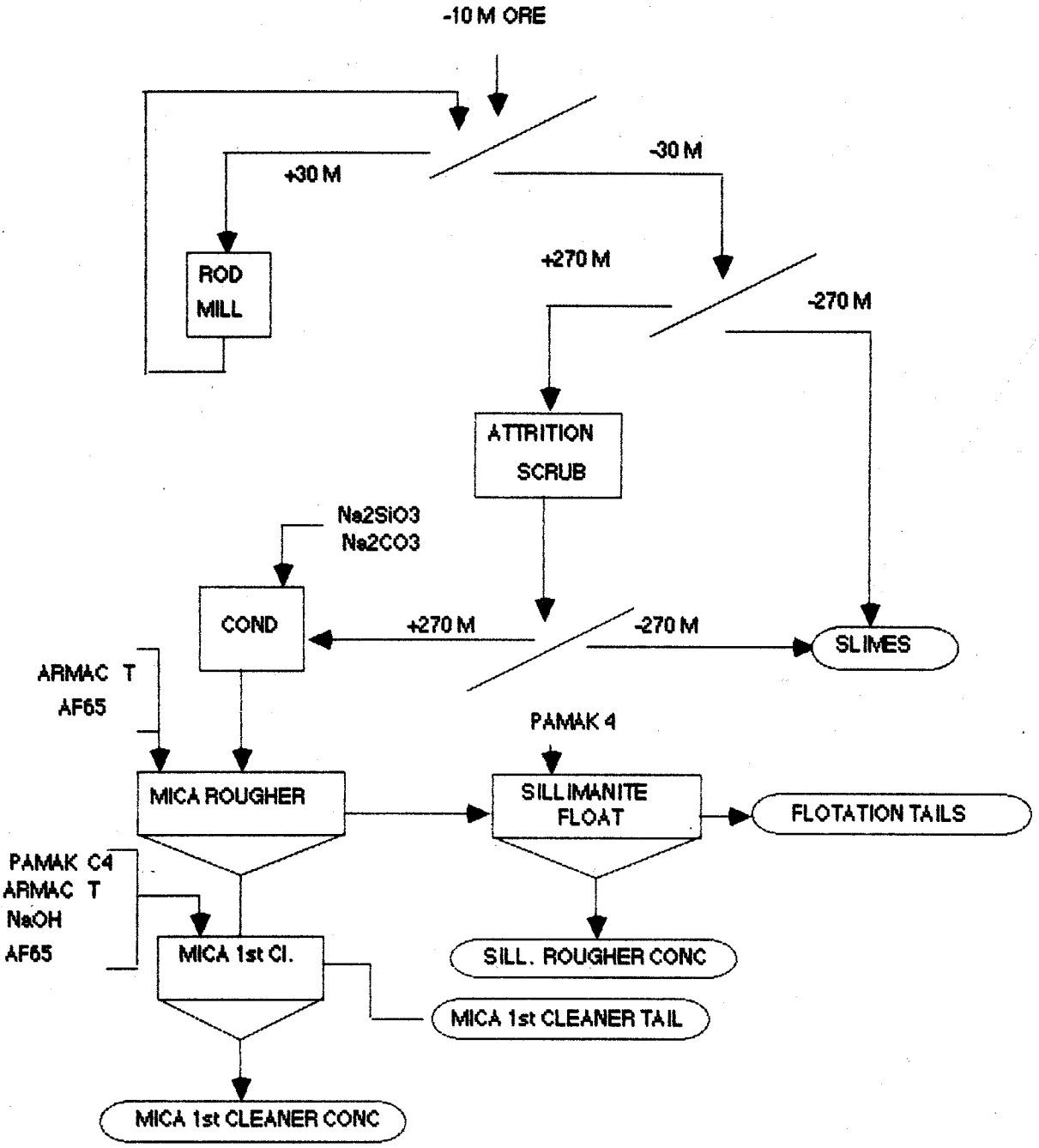
Stage	Attrition Scrub	Mica Cond	Mica Float	Sillimanite Cond	Sillimanite Float
Flotation Cell	Wemco	1000gD-1	1000GD-1	1000g D-1	1000g D-1
Speed rpm	700	1800	1800	1800	1800
% Solids	60	50	30	50	30

Test No. CL3

Product	Wt %	Assay % Mica	Quartz	Sillimanite	Garnet	Magnetite
Mica 1st Cleaner Conc	28.51	84.0	15.0	0.0	0.0	1.0
Mica 1st Cleaner Tail	2.15	80.0	12.0	5.0	2.0	1.0
Sill. Rougher Conc	6.11	70.0	10.0	18.0	1.0	1.0
Flotation Tails	50.49	25.0	30.0	35.0	10.0	2.0
-270 Slimes	12.73	48.8	23.3	21.6	5.9	1.6
Head(calc)	100.00	48.8	23.3	21.6	5.9	1.6

	% Distribution Mica	Quartz	Sillimanite	Garnet	Magnetite
Mica 1st Cleaner Conc	49.1	18.4	0.0	0.0	18.1
Mica 1st Cleaner Tail	3.5	1.1	0.5	0.7	1.4
Sill. Rougher Conc	8.8	2.6	5.1	1.0	3.9
Flotation Tails	25.9	65.1	81.7	85.5	64.0
-270 Slimes	12.7	12.7	12.7	12.7	12.7
Head(calc)	100.0	100.0	100.0	100.0	100.0

TEST No. CL3 FLOWSHEET



Test CL-3 - Continued

Screen Analysis

Combined Product

Mesh Size (Tyler)	% Retained Individual	% Retained Cumulative	% Passing Cumulative
+ 28	0.4	0.4	99.6
35	9.0	9.4	90.6
48	20.6	30.0	70.0
65	16.1	46.1	53.9
100	14.5	60.6	39.4
150	10.1	70.7	29.3
200	6.4	77.1	22.9
270	4.5	81.6	18.4
400	4.1	85.7	14.3
- 400	14.3	100.0	-
Total	100.0	-	-

TEST NO. OC-1

Purpose: To investigate the separation of Mica from sillimanite and garnet using the acid cationic flowsheet.

Procedure: As outlined below.

Feed: 1 kg of -10 mesh Otter Creek ore.

Grind: 5.5 min/kg at 50 % solids in the 2 kg rod mill.

Conditions:

	Reagents Added, grams per tonne					Time, minutes			pH
	NaOH	H2SO4	Armac T	Pamak C4	AF65	Grind	Cond.	Froth	
Grind Deslime on 200 mesh	1650	-	-	-	-	5	-	-	-
Mica Cond 1	-	350	-	-	-	-	3	-	4.0
Mica Cond 2	-	35	200	-	35	-	3	-	4.0
Mica Ro	-	-	-	-	-	-	1	3	4.0
	-	140	100	-	15	-	1	3	4.0
	-	105	100	-	-	-	1	3	4.0
Mica 1st Cl	-	70	-	-	-	-	1	3	4.0
Mica 2nd Cl	-	70	-	-	-	-	1	1.5	4.0
*Sillimanite Ro	-	-	-	300	21	-	1	5	7.0

*very little floating, stable froth

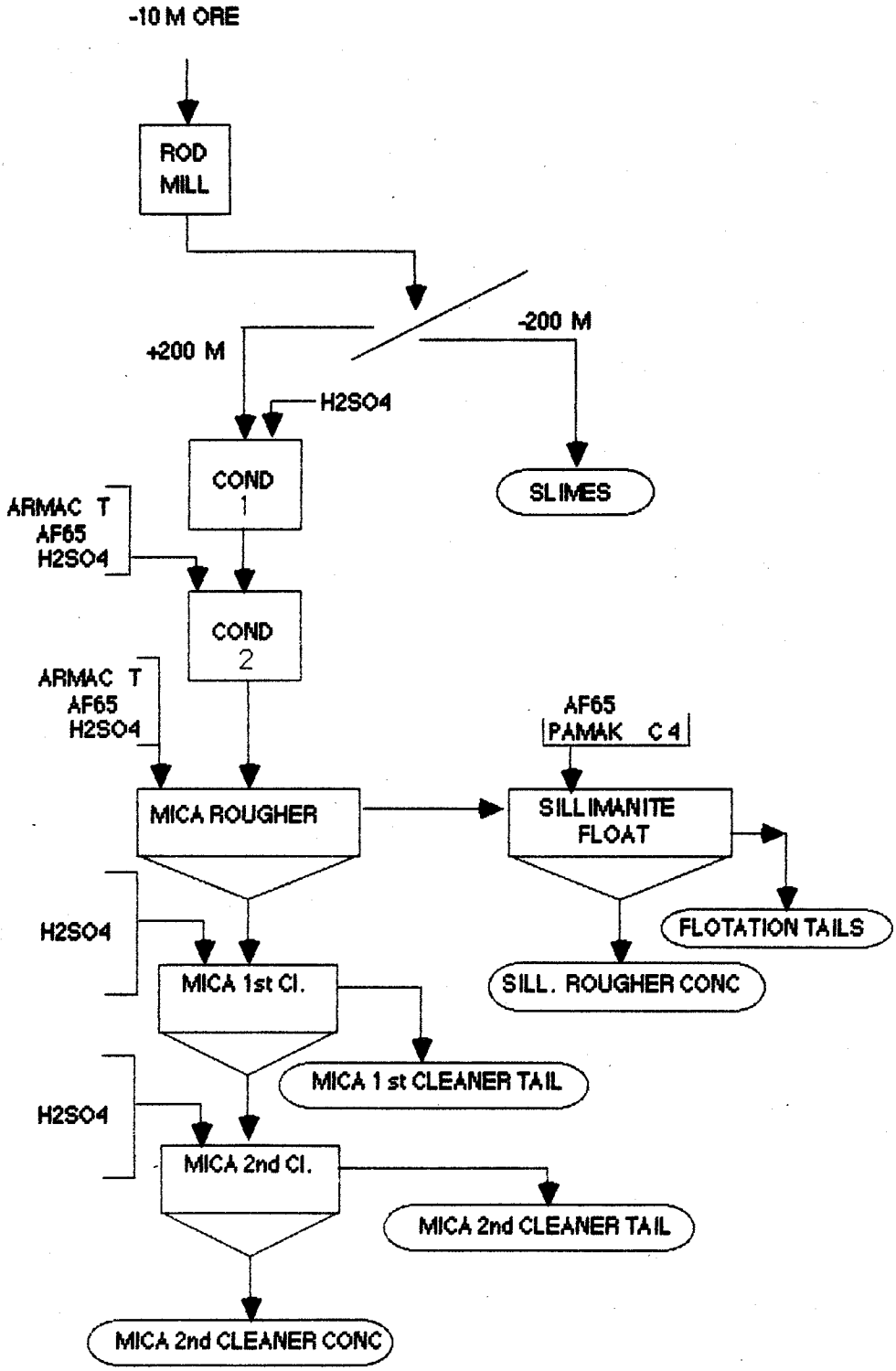
Stage	Mica Cond 1+2	Mica Rougher	Mica 1st+2nd Cls	Sillimanite Ro
Flotation Cell	1000	1000g D-1	1000g D-1	500g D-1
Speed rpm	1000	1300	1500	1400
% Solids	40-45	30	-	-

Test No. OC1

Product	Wt %	Assay % Mica	Quartz	Sillimanite	Garnet	Magnetite
Mica 2nd Cleaner Conc	27.86	75.0	12.0	8.0	3.0	2.0
Mica 2nd Cleaner Tails	9.04	60.0	25.0	12.0	1.0	2.0
Mica 1st Cleaner Tails	6.77	54.0	25.0	16.0	2.0	3.0
Sill. Rougher Conc	0.77	28.0	38.0	20.0	12.0	2.0
Flotation Tails	46.95	37.0	20.0	33.0	8.0	2.0
-270 Slimes	8.61	52.0	18.6	21.9	5.4	2.1
Head(calc)	100.00	52.0	18.6	21.9	5.4	2.1

	% Distribution Mica	Quartz	Sillimanite	Garnet	Magnetite
Mica 2nd Cleaner Conc	40.1	18.0	10.2	15.6	26.9
Mica 2nd Cleaner Tails	10.4	12.2	4.9	1.7	8.7
Mica 1st Cleaner Tails	7.0	9.1	4.9	2.5	9.8
Sill. Rougher Conc	0.4	1.6	0.7	1.7	0.7
Flotation Tails	33.4	50.5	70.6	69.9	45.3
-270 Slimes	8.6	8.6	8.6	8.6	8.6
Head(calc)	100.0	100.0	100.0	100.0	100.0

TEST No. OC 1 FLOWSHEET



Test No. OC-1 - Continued

Screen Analysis

Combined Product

Mesh Size (Tyler)	% Retained Individual	% Retained Cumulative	% Passing Cumulative
+ 10	0.1	0.1	99.9
14	0.7	0.8	99.2
20	1.5	2.3	97.7
28	6.0	8.3	91.7
35	14.2	22.5	77.5
48	16.1	38.6	61.4
65	15.1	53.7	46.3
100	10.5	64.2	35.8
150	9.7	73.9	26.1
200	6.2	80.1	19.9
270	4.7	84.8	15.2
400	2.8	87.6	12.4
- 400	12.4	100.0	-
Total	100.0	-	-