CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

OTTAWA

IR 72-28 June 1972

BENEFICIATION OF TREMOLITE (PROJECT MP-IM-7113)

by

R. A. Wyman

Mineral Processing Division

Note: This report relates essentially to the samples as received. The report and any correspondence connected therewith shall not be used in full or in part as publicity or advertising matter.

COPY NO.

Mines Branch Investigation Report IR 72-28

BENEFICIATION OF TREMOLITE (PROJECT MP-IM-7113)

by

R. A. Wyman*

- - - -

SUMMARY

Wet and dry comminution, screening, and gravity beneficiation trials with some magnetic separation were directed towards improving the brightness of finely ground tremolite. Brightness can be slightly improved by dry reduction and slightly more improved by wet reduction but at the expense of about half the feed and of a drying step.

With a general objective of products for filler use, the chief evaluating factor was brightness in comparison with magnesium carbonate, as determined on minus 325-mesh samples. The feed brightness was found to be 87. Dry tabling of 35 to 48- and 48 to 100-mesh material yielded products of 89.5 and 88 brightness, respectively. Wet tabling with subsequent grinding and screening of 35 to 100-mesh material yielded products of 90 brightness.

These results suggest minimum processing such as comminution, air classification, and either screening or air tabling of oversize.

---

* Head, Industrial Minerals Milling Section, Mineral Processing Division, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

CONTENTS

TABLES

INTRODUCTION

The Division was originally approached, in May, 1971, by Dr. C. C. Allen of Ram Petroleums Limited regarding four sections of diamond drill core from Lot 6, Concession 6, Palmerston Township, Ontario. This request was for information on the core material and its potential as a filler. A number of experiments were performed on the core samples supplied.

In September, 1971, Mr. Bertrand Robinson, P. Eng., contacted the Division, as a consultant for the project, with a request for an extension of the investigation. After establishing Mr. Robinson's connection with Ram Petroleums Limited, the Division agreed to provide materials for market exploration by grinding and sizing selected portions from bulk samples supplied.

In November, 1971, a 50-pound lot, selected from core and surface sampling, was received with a request for beneficiation experiments aimed at establishing a practical process to supply marketable products. This extension of the investigation was predicated on the assurance that acceptable mineable tonnages had been established on the property. The Division agreed to explore the prospects for beneficiation of this 50-pound lot.

SAMPLES

The first sample received, designated MPD 71/31, consisted of four core sections as follows:

Hole	No.	1	from 23 to 27 feet
"	"	"	37 to 42 "
"	"	"	42 to 45 "
"	"	"	45 to 48 "

The second sample received, designated MPD 71/55, was composed of two lots of split drill core, approximately 60 pounds each, and one lot of fibrous tremolite, approximately 35 pounds.

The third sample, designated MPD 71/81, contained a mixture of selected drill core and fibrous tremolite. This core was said to be from a new drill hole.

MINERALOGY

The approximate mineral composition of the deposit, as reported by Ram Petroleums Limited from studies of thin sections, is 40 to 50 % tremolite, 30 to 35% phlogopite mica, and 20 to 25% quartz. No talc, carbonate, or other alteration products were detected. For this report, "tremolite", or "coarse", are terms used to depict the non-mica portion, i.e., tremolite plus quartz.

WORK PERFORMED

Sample MPD 71/31

The initial stages of this investigation developed through the Non-Metallic and Waste Minerals Section of the Division and consisted essentially of passing small samples of ground material, prepared from a composite of the drill core, through the Jones Wet Magnetic Mineral Separator.

The first trial included portions of the four core sections supplied. Over 8% of the feed was removed as magnetics without a complete elimination of dark material from the non-magnetics. A second composite was prepared from the last three sections of drill core, i.e., 37 to 42, 42 to 45, and 45 to 48 feet, in proportion to the total footage of each section. This was done because most of the dark material appeared from the first section, i.e., 23 to 27 feet.

This composite sample was reduced to minus 28-mesh by jaw and rolls crushing and screening. Microscopic examination, for dark material in the products, was used as a guide, and brightness was determined by Hunter Difference Colorimeter on the final, or "best", products developed.

The initial trial was on the minus 28-mesh feed using the Jones Separator. The non-magnetic fraction contained mixed grains, i.e., white grains with dark attachments, therefore the second trial was made after grinding the minus 28-mesh feed for 10 minutes in a pebble mill. Although this produced a non-magnetic product containing 32.7% minus 325-mesh (as compared to 18.5% minus 325-mesh in the minus 28-mesh feed) it also contained mixed grains.

For the third trial, the minus 28-mesh feed was pebble milled for 30 minutes. This produced 50.8% minus 325-mesh in the non-magnetic product, but mixed grains were still present. Because of this a variation was made in the approach. The minus 28-mesh feed was first ground for 30 minutes in a pebble mill then screened into fractions. Only the minus 325-mesh was passed through the Jones Separator.

The results of this trial are shown in Tables 1 and 2. Table 1 shows the screen fractions of the product of 30 minutes of pebble milling, and Table 2 shows the fractions obtained from magnetic separation.

TABLE 1

Screen Fractions From 30-Minute Grind

Fraction	Wt. %	Comment
plus 48 mesh	2.7	↑
48 to 65 "	4.4	
65 to 100 "	8.1	Chiefly
100 to 150 "	7.1	Mica
150 to 200 "	11.0	
200 to 325 "	17.1	↓
minus 325 "	49.6	Feed for Magnetic Separator
	100.0	

TABLE 2

Jones Separation of minus 325-mesh

(High-intensity plates. Highest field)

Fraction	Wt %	Wt. % of Original Feed	Brightness*
Magnetics	10.0	4.9	
Middlings	43.9**	21.8	86.4
Non-Magnetics	46.1**	22.9	86.5
	100.0	49.6	

* Compared to magnesium carbonate as 100%

** 90% of 49.6% (minus 325-mesh, Table 1) or 44.6% of original feed.

Sample MPD 71/55

The purpose of this sample was twofold: first, to provide some material for a market survey and, second, to provide feed for proposed beneficiation trials. The sample was composed of two core lots and one fibrous tremolite lot from a bulk exposure on surface at the deposit.

Approximately 10 pounds of tremolite was removed from Core Lot A. This 10 pounds was designated D. The second core lot(B) was reduced by jaw crusher to pass 1 inch and was retained for possible beneficiation. The fibrous material was designated C. The remainder of A was held for possible further work.

Lot D was gradually reduced by jaw and rolls crushing to pass 28 mesh. A very small amount (less than one ounce) of mica reported with the plus 28-mesh. This was excluded from further reduction. The minus 28-mesh was placed in a large jar mill with 22 pounds of 1/2 -inch cylpebs (fused aluminum cylinders) and ground dry for 2 hours. The mill was dumped and the batch was screened on a 325-mesh sieve. Plus 325-mesh was reground for 90 minutes. The product was screened on 100- and 325-mesh sieves, and approximately 2 ounces of mica was recovered as plus 100-mesh. The 100 to 325-mesh material was reground for 1 hour, and the product was screened on 200- and 325-mesh sieves. One ounce of mica was recovered as plus 200-mesh and two ounces, mostly tremolite but with some mica, was recovered as a 200 to 325-mesh product. The minus 325-mesh product weighed slightly more than 9.5 pounds.

Lot C was treated in a similar fashion but due to the needle shape of the particles it was found preferable to pulverize the crusher product in an impact machine. This produced an appreciable amount of minus 325-mesh which was screened out. The plus 325-mesh was then ground in batches in the large jar mill in a medium of 22 pounds of 1/2-inch cylpebs; the minus 325-mesh was removed by periodical screening. After 6 hours of grinding per batch, it was possible to remove about 3 ounces of plus 48-mesh as mica. After another hour of grinding, about 10 ounces of plus 100-mesh were removed as mica. After a further 3 1/2 hours grinding, at this point with all plus 325-mesh combined, it was possible to remove 5 1/2 ounces of plus 200-mesh as mica. After 30 minutes' more grinding, 11 ounces of plus 325-mesh material remained. This was largely acicular tremolite with some mica. The minus 325-mesh from the original batch reductions was combined as product C-1, and that from final reduction of combined batches was combined as product C-2. This was done because the material from the final reduction stages was obviously darker than that from the primary reduction stages.

A summary of the work on Sample MPD 71/55 is given in Table 3.

TABLE 3

Summary of Work on Sample MPD 71/55

Lot	D (lb)	Brightness	C (lb)	Brightness
Fraction				
plus 28 mesh	0.05			
plus 48 "			0.19	
28 to 100 "	0.12			
48 to 100 "			0.62	
100 to 200 "	0.05		0.34	
200 to 325 "	0.15		0.70	
minus 325 "	9.52	88.3	23.81(C-1)	87.0
minus 325 "			4.89(C-2)	82.5
Total	9.89		30.55	

Sample MPD 71/81

The principal beneficiation trials were performed on this sample. Both wet and dry methods were applied. Because the available material comprised only 50 pounds, the experiments were mainly bench scale. Filler applications were the objective, so product brightness (of minus 325-mesh powder compared with magnesium carbonate as 100%) was used as the main basis of assessment. This was determined by means of a Welch "Densicron" Optical Density Meter.

A characteristic of this material, as with most minerals of the type, is that it becomes brighter as it is reduced in size. Four separate samples riffled from the feed at minus 28-mesh were checked for brightness, ground to pass 100 mesh and checked, then ground to pass 325 mesh and again checked. Results are given in Table 4.

TABLE 4

Feed Brightness

Sample	Minus 28-mesh	Minus 100-mesh	Minus 325-mesh
1	71.0	81.0	87.0
2	74.0	81.5	87.5
3	72.5	80.5	86.5
4	72.0	81.5	87.0
Average	72.4	81.1	87.0

Dry Trials

1) Rolls and Screen. Approximately 1/2 pound of minus 4-mesh feed was passed through the laboratory rolls set at 1/8 - inch gap. Insufficient reduction was obtained. The lot was repassed through the rolls set at 1/16-inch gap. This produced a good deal of compaction as well as size reduction. The compaction products had to be broken up by brushing on a 14-mesh screen. The plus 14-mesh contained about 25% mica but minus 14-mesh screen fractions contained no pronounced mica concentration. This approach was not considered promising;

2) Disc Pulverizer and Screen. About 1/2 pound of minus 4-mesh feed was reduced to nominal minus 14-mesh by jaw crushing. This was passed through a Braun disc pulverizer set at 1/16-inch opening. The reduction in size was slight so the lot was passed through the pulverizer set at a 1/32-inch opening. The plus 14-mesh resulting comprised 0.3% of the feed weight and contained about 60% mica. The 14 to 20-mesh fraction comprised 0.5% of the feed weight and contained about 40% mica. The minus 14-mesh feed was passed through the pulverizer set at a 1/64-inch opening. The 14 to 20-mesh resulting comprised 0.2% of the feed weight and contained about 75%

mica. The 20 to 35-mesh comprised 1.0% of the weight and contained about 50% mica. Remaining fractions showed little mica concentration. This approach was also considered unpromising.

3) Impactor and Screen. About 1/2 pound of minus 4-mesh feed was passed through a small hammer mill (Micro-Pulverizer) using a 1/16-inch opening, slotted screen, and slow rotation. This did not provide enough reduction. The operation was repeated at fast rotation. Reduction was still insufficient. With substitution of a 1/32-inch slotted screen, and a repeat of the operation using medium speed of rotation, a top product of plus 20-mesh representing 0.1% of the feed weight and all mica was obtained. However, the 20 to 35-mesh product represented 20% of the feed with about 10% mica content. Rerunning the minus 20-mesh fraction with the same screen and faster speed produced a 20 to 35-mesh fraction that represented 10% of the feed weight and contained about 25% mica. This approach was not considered too promising.

4) Rod Mill and Screen. A Denver 6 x 12-inch rod mill was set up for continuous operation and charged with 30 pounds of 1/2-and 3/4-inch stainless-steel rods. The minus 4-mesh feed was supplied at 16 lb/hr until approximately an equal weight was obtained from the discharge. Discharge was then sampled and the operation was stopped. The results are shown in Table 5.

TABLE 5

Results of First Rod Mill Trial

Fraction	Wt. %	Approx. Mica %
plus 14 mesh	0.6	30
14 to 20 "	1.9	15
20 to 35 "	11.6	10
35 to 65 "	25.7	5
minus 65 "	60.2	
Total	100.0	

The rod milling operation was repeated with all conditions the same except that a rod charge of 45 pounds was used. The results are shown in Table 6.

TABLE 6

Results of Second Rod Mill Trial

Fraction	Wt. %	Approx. Mica %
plus 14 mesh	0.3	50
14 to 20 "	0.6	40
20 to 35 "	3.6	15
35 to 65 "	22.2	5
minus 65 "	73.3	
Total	100.0	

As a method of removing mica by grinding and screening this approach did not appear too promising.

5) Ball Mill and Screen. As a trial for ball milling and to conserve the feed sample, a batch set-up was used. This consisted of a medium-size jar mill charged with 2300 grams of 1/2 - inch cylpebs and 500 grams of minus 4-mesh feed. This was allowed to rotate for 1 hour at 80 RPM. Results are shown in Table 7.

TABLE 7

Results of First Ball Mill Trial

Fraction	Wt. %	Approx. Mica %
plus 14 mesh	4.4	(mostly 4 to 8 mesh)
14 to 20 "	0.4	60
20 to 35 "	0.8	80
35 to 65 "	3.2	75
minus 65 "	91.2	
Total	100.0	

Using the same cylpeb charge but 500 grams of minus 10-mesh feed, the operation was repeated for a 30-minute run at 80 RPM. Results are shown in Table 8.

TABLE 8

Results of Second Ball Mill Trial

Fraction	Wt. %	Approx. % Mica
plus 14 mesh	0.2	50
14 to 20 "	0.8	60
20 to 35 "	3.4	50
35 to 65 "	14.2	30
minus 65 "	81.4	
Total	100.0	

A third trial was made using the same cylpeb charge and amount of minus 10-mesh feed but running for 60 minutes at 80 RPM. Although there seems to be no adequate explanation, this produced almost the same amount of minus 65-mesh as had the 30-minute grind, i.e., 81%. The trial was, however, extended by screening out the plus 65-mesh, the 65 to 100-mesh, the 100 to 325-mesh, and the minus 325-mesh fractions. The minus 325 fraction was set aside. The 65 to 100-mesh fraction was found to be virtually all mica and was also set aside. The remaining material, about 47% of the original batch, was returned to the mill and reground for another hour. This was screened into various fractions.

A summary of the third ball-milling operation is provided in Table 9.

TABLE 9

Summary of Third Ball Mill Trial

Fraction (mesh)	Grinding Time (hour)	Wt %	Approx. Mica (%)
65 to 100	1	3.2	95
minus 325	1	49.8 (1)	
plus 65	2	3.6	(Mixed coarse)
65 to 100	2	0.7	95
100 to 200	2	1.9	90
200 to 325	2	5.1	± 80
minus 325	2	35.7 (2)	
Total		100.0	
Combined			Brightness
minus 325 (1)		49.8	84.5
minus 325 (2)		35.7	89.0
"Mica"		10.9	
Coarse		3.6	
Total		100.0	

Although ball milling and screening as a means of mica removal was not completely satisfactory, it did appear to be the most promising method. However, the average brightness of fine product was no better than that for grinding the entire feed to pass 325-mesh (Table 4).

6) Winnowing. Because a tendency was apparent in the comminution trials for tremolite to remain with mica in the 14 to 65-mesh sizes an attempt was made to see if some separation could be made in these sizes by air winnowing. The set-up consisted of an open-ended box divided into three compartments in the lower half, but open in the upper half. A vibrating feeder was placed to discharge a gentle ribbon of feed into the first compartment and a controllable, gentle air jet was placed to blow through the feed ribbon toward the second and third compartments.

After several trials to obtain suitable feed and air flow, a trial was made on 20 to 35-mesh feed containing approximately 25% mica. A good result was obtained with close to 75% of the feed almost free of mica reporting in the first compartment, and 25% of the feed, almost entirely mica, reporting in the second and third compartments (combined).

A similar trial using 35 to 65-mesh feed was not quite so successful. This feed contained around 15% mica. About 75% by weight reported in the first compartment and contained 1 to 2% mica. The remaining 25% reported in the second and third compartment and was composed of mica mixed with very fine tremolite.

This method might be difficult to apply on a large scale although it was reasonably successful on the scale used.

7) Air Tabling. Trials with a small Knapp and Bates air table were used on the coarser sizes of the comminution products. Using 28 to 35-mesh feed and after preliminary trials to establish favourable conditions, a run was made from which the middlings were rerun, and the rerun middlings again rerun. Mica evolving from the roughing and two cleaning stages was combined. Similarly the segregated tremolite was combined. The small amount of remaining middlings was kept separate. This operation is summarized in Table 10.

TABLE 10

Summary of Air Table Trial on 28 to 35-Mesh Feed

Settings	Pitch: 2° Feeder: 80 to 90	Slope: 0° Air: Medium Deck Vibration: 2
Products	Wt. %	Brightness of minus 325-Mesh
Mica	1.4	
Midds	7.9	
Tremolite	90.7	87.5

With 35 to 48-mesh feed, the middlings from the roughing stage were cleaned once. Again mica and tremolite products were combined. This operation is summarized in Table 11.

TABLE 11

Summary of Air Table Trial on 35 to 48-mesh Feed

Settings	Pitch: 5° Feeder: 80 to 90	Slope: 5° Air: Low Deck Vibration: 3
Products	Wt. %	Brightness of minus 325-Mesh
Mica	5.2	
Midds	13.1	
Tremolite	81.7	89.5

A final trial was made with 48 to 100-mesh feed, almost too fine for successful air tabling. Again middlings from the roughing stage were cleaned once with mica and tremolite products being combined. A summary is given in Table 12.

TABLE 12

Summary of Air Table Trial on 48 to 100-mesh Feed

Settings	Pitch: 3 to 4° Feeder: 85 to 90	Slope: 3 to 4° Air: low Deck Vibration: 3
Products	Wt. %	Brightness of minus 325-Mesh
Mica	10.0	
Midds	26.2	
Tremolite	63.8	88.0

It is notable that with decreasing fineness of feed to the table the tremolite product became smaller in amount but retained its brightness. Amounts reporting as mica became increasingly larger and lower in real mica content. Amounts left as middlings became increasingly larger.

Tabling would probably be useful in producing a mica product from the minus 48-mesh sizes should such fractions be developed. It will be observed, however, that there is only a slight improvement in the brightness of table products over the result obtained for grinding the whole feed sample to minus 325 mesh. An anomaly occurred during the table trials in that minus 100-mesh remaining from the table feed preparation had a brightness of 86.5 compared to that from feed (Table 4) at 81%.

8) Air Classification. Trials were made with three types of air or dust classifier. These were laboratory models suitable for small lots of feed and the results obtained were not particularly favourable. However, a large variety of commercial machines suitable for this type of separation are available on the market.

The feed used was minus 65-mesh accumulated from the various comminution trials.

The first trial was made with a Walther Laboratory Air Classifier No. 150, at settings for coarsest separation. This equipment is designed for separation at fine (few-micron) sizes so it was immediately apparent that the feed was too coarse. Practically no product appeared in the fines fraction.

The second machine tried was a Raymond Laboratory Air Classifier. This was set up for average separation. The first, or rougher, pass removed 15.5% of the feed as a fine fraction, but a rerun or cleaner pass on the coarse fraction removed 2.3% more fines. Repeating the operation at coarse settings produced a fine fraction of 23.9% whereas the cleaner stage produced 8.6% more fines. Unfortunately the fine products, though relatively mica-free, were contaminated by the aluminum construction members in the equipment.

Several trials were made with a laboratory Federal Dust Classifier system. This is essentially a primary and a secondary cyclone and a bag collector. The equipment delivers a coarse fraction from the primary cyclone, a middling (or somewhat finer fraction) from the secondary cyclone and a fine fraction from the bag collector. Air is drawn through the system by a fixed-speed vacuum fan, and control is obtained through the amount of air which is allowed to enter with the feed into the primary cyclone, and into the secondary cyclone. The trials are summarized in Table 13.

TABLE 13

Summary of Federal Dust Classifier Trials

Run No.	1	2	3	4	5
Air Settings					
Feed	5	15	25	10	20
Primary	5	15	25	20	20
Secondary	5	15	25	30	30
Products (%)					
Coarse	81.8	28.6	50.1	21.8	42.1
Midd	16.8	43.4	12.7	74.7	11.3
Fine	1.4	28.0	37.2	3.5	46.6
Total	100.0	100.0	100.0	100.0	100.0
Brightness			72.0		72.5

The low reflectivity of fine products cannot be completely accounted for but it probably is caused by contamination from comminution handling, and the classifier itself, and by the samples not having been reground, in this particular case, to minus 325-mesh prior to taking brightness readings.

9) Photometric Sorting. This approach was considered, but no trials were made. The material would not be a good feed due to the shape factor, especially the fibrous variety. Moreover, it had been demonstrated that the contaminants which reduced brightness were relatively fine, certainly much finer than the 4-mesh, limiting particle size for photometric sorting.

Wet Trials

1) Rod Mill and Screen. The same rod mill that was used for the dry trials was employed. The rod charge was 45 pounds in the 1/2- and 3/4-inch sizes, and the feed was minus 4-mesh at a rate of 18 lb/hr. Water was added at a rate of 18 lb/hr (approximately 50% solids). The operation was carried to the point where discharge roughly equalled input. Samples were then taken and the operation was stopped. The results of this trial are given in Table 14.

TABLE 14

Results of Wet Rod Mill Trial

Fraction	Wt %	Approx. (%) Mica
plus 14 mesh	0.3	(to $\pm$ 4-mesh)
14 to 20 "	0.1	40
20 to 35 "	0.6	30
35 to 65 "	20.7	20
65 to 325 "	57.5	5 to 10
minus 325 "	20.8	(dark specks visible)
Total	100.0	

2) Ball Mill and Screen. The same batch method as was used for the dry trials was applied. The first trial used 2300 grams of 1/2-inch cylpebs, 500 grams of minus 4-mesh feed, and 500 ml of water (to give 50% solids). The mill was rotated for 1 hour at 80 RPM. The results are shown in Table 15.

TABLE 15

Results of First Wet Ball Mill Trial

Fraction	Wt %	Approx. (%) Mica
plus 14 mesh	8.6	(coarse sizes)
14 to 20 "	0.2	10
20 to 35 "	0.3	50
35 to 65 "	1.9	75
65 to 100 "	2.9	75
100 to 200 "	14.3	50
200 to 325 "	15.9	25
minus 325 "	55.9	-
Total	100.0	

For the second and third trials the same conditions were repeated, except that the feed was minus 10-mesh. For the second trial the mill was rotated for 30 minutes at 80 RPM, and for the third trial for 60 minutes. Results are shown in Table 16.

TABLE 16

Results for Second and Third Ball Mill Trials

Duration	30 min.		60 min.	
Fraction	Wt. %	Approx. Mica(%)	Wt. %	Approx. Mica(%)
plus 14 mesh	0.8	5	<0.1	10
14 to 20 "	0.6	10	<0.1	75
20 to 35 "	1.5	60	0.2	85
35 to 65 "	6.4	40	1.7	85
65 to 100 "	12.1	25	2.6	85
100 to 200 "	30.7	10	13.8	30
200 to 325 "	15.7	2	20.9	2
minus 325 "	32.2		60.6	
Total	100.0	9.96	100.0	8.47

It is apparent from Table 16 that longer grinding had the general effect of moving tremolite toward the fine sizes while leaving mica in the coarser sizes.

A fourth trial was made, elaborating somewhat on the third. All conditions were the same for the first 60 minutes of grind. At this point the product was separated into screen fractions at 65, 100, and 325 mesh. The minus 325-mesh fraction was set aside. The 65 to 100-mesh was virtually all mica and was set aside. The 100 to 325-mesh and plus 65-mesh was virtually all mica and was set aside. The 100 to 325-mesh and plus 65-mesh fractions were reground for 60 minutes, and the product was screened. This operation is summarized in Table 17. Note that this procedure is similar to the dry one summarized in Table 9.

TABLE 17

Summary of Fourth Ball Mill Trial

Fraction (mesh)	Grinding Time (hours)	Wt %	Approx. % Mica
65 to 100	1	3.6	95
minus 325	1	53.8(1)	
plus 65	2	1.8	(Mixed coarse)
65 to 100	2	0.3	95
100 to 200	2	2.1	85
200 to 325	2	2.8	75
minus 325	2	35.6 (2)	
Total		100.0	
Combined			Brightness
minus 325 (1)		53.8	85.5
minus 325 (2)		35.6	88.5
"Mica"		8.8	
Coarse		1.8	
Total		100.0	

The similarity of results between Tables 9 and 17 may be readily observed both for overall minus 325-mesh product and for brightness. It is curious that the 1-hour grind product in each case was less bright than the 2-hour product.

3) Superpanner. As a guide to the prospects for tabling, several small samples were worked into fractions by superpanning. The first was of minus 35-mesh and proved to have too broad a size spectrum for good separation of minerals. The second was the 35 to 100-mesh portion, and the third the minus 100-mesh portion. Sharper separations were obtained in these trials. A summary of the superpanner results is given in Table 18.

TABLE 18

Superpanner Results

Feed Size	Minus 35-Mesh	35 to 100-Mesh		Minus 100-Mesh	
Fraction	Wt %	Wt %	Brightness	Wt %	Brightness
Fines	22.4	--		25.6	89.5
"Mica"	21.6	33.3		25.1	
Coarse	56.0	66.7	90.5	49.3	89.0
Total	100.0	100.0		100.0	

4) Tabling Because of the superpanner indications, the same 35 to 100- and the minus 100-mesh were passed over a 40 x 18-inch Wilfley table. A summary of the table trials is given in Table 19.

TABLE 19

Summary of Wilfley Table Trials

Slope 5 deg Water flow, moderate

Feed Size	35 to 100-Mesh		Minus 100-Mesh	
Fractions	Wt %	Brightness	Wt %	Brightness
Fines			26.8	88.0
Mica	23.3	83.5	50.2	76.5
Coarse	76.7	86.5	23.0	89.5
Total	100.0		100.0	

Although not strictly part of the tabling operation, the work was extended to include grinding of the table products. In the first case, 500 grams of the 35 to 100-mesh coarse material was ground for 1 hour at 50% solids in the usual jar mill with 2300 grams of 1/2-inch cylpebs. This was screened on 100- and 325-mesh screens, the plus 100 being isolated as a mica product and the minus 325 being set aside. The 100 to 325-mesh was returned to the mill and ground for a second hour then screened into fractions. The results of this operation are given in Table 20.

TABLE 20

Grinding of 35 to 100-Mesh Table Product

Fraction (mesh)	Grinding Time (hour)	Wt %	Approx. % Mica	Brightness
plus 100	1	7.9	90	
minus 325	1	40.3		89.5
plus 200	2	0.8	95	
200 to 325	2	3.2	85	
minus 325	2	47.8		90.5
Total		100.0		

Similarly, the fines plus the coarse fractions, from the minus 100-mesh table run (Table 19), were combined according to their weights and ground for one hour at 50% solids with 2300 grams of cylpebs, then screened on 200- and 325-mesh. The result of this effort is given in Table 21.

TABLE 21

Grinding of Minus 100-Mesh Table Product

Fraction	Wt %	Approx. % Mica	Brightness
plus 200 mesh	2.4	90	
200 to 325 "	9.6	80	
minus 325 "	88.0		87.5
Total	100.0		

5) <u>Wet Classification</u>. Simple wet classification trials were also made on minus 100-mesh material. A 500-ml graduate was used. This was placed in a pail. Water at a regular rate was supplied from a constant-head tank. For the first trial, 50 grams of minus 100-mesh were stirred into 500-ml of water in the graduated cylinder. Water was introduced at the bottom of the cylinder from the head tank, via a glass tube, at a rate of 80 ml/min. Overflow from the cylinder was collected in the pail and the glass tube was used for occasional stirring of material settled at the bottom of the cylinder. After 15 minutes the overflow was virtually clear, the material collected was considered to be the finest fraction of feed, and was designated "A". Water flow was then increased to 170 ml/min and the process repeated. After 10 minutes the overflow was clear and the fraction collected was designated "B". Water flow was finally increased to 450 ml/min. After 7 minutes the overflow was clear and the collected fraction was designated "C". Material remaining in the cylinder, the coarsest fraction of feed, was designated "D". Results are shown in Table 22.

TABLE 22

Results of First Wet Classification Trial

Fraction	Wt %	Brightness
plus 100 mesh	4.5	
A	26.9	87.5
B	21.6	81.0
C	27.9	
D	19.1	
Total	100.0	

For the second classification trial the same set-up was used but the procedure was simplified. Water was introduced at a flow of 100 ml/min for 20 minutes by which time the overflow was clear. It was assumed that the relatively coarse remainder, which contained about 20% mica, would be suitable for table feed. Results are shown in Table 23.

TABLE 23

Results of Second Wet Classification Trial

Fraction	Wt %	Brightness
plus 100-mesh	4.5	
Overflow	41.2	86.0
Coarse	54.3	
Total	100.0	

6) Magnetic Separation. Because a small amount of dark material could be observed in the overflow product from the second classification trial, and to further test the effectiveness of magnetic separation, this fraction was passed through the Jones laboratory model. The portion removed as magnetics amounted to 1.1% (or 0.5% of the original feed). The non-magnetic portion was observed to still contain some dark specks. Brightness of the non-magnetics remained 86.0 (see Table 23). This might be compared with the work on Sample MPD 71/31 as reported in Table 2.

7) Flotation. Because the overall reduction of mica by the methods tried had not resulted in a marked degree of brightness improvement, the somewhat more costly application of flotation would be unlikely to produce any more pronounced improvement. This could not be decided without fairly extensive flotation trials aimed at removing the phlogopite.

DISCUSSION

Certain peculiarities of this material were pointed up by the experimental work. In comminution, only a minor release of mica took place above 35 mesh. The tremolite and quartz tended to be more resistant to grinding than the mica; small amounts but by no means all of the mica could be removed by screening down to 325-mesh. Grinding the whole feed to minus 325-mesh, either wet or dry, produced a product with brightness of about 87 on both small "head" samples and bulk lots. However, the bulk grinding revealed vagaries in that, for Sample MPD 71/55, the first part of feed ground to minus 325-mesh had a brightness of 87 whereas the last of the feed produced a brightness of 82.5. Wet and dry ball mill trials on Sample MPD 71/81 gave a reversal of this in that minus 325 produced from 1 hour of grind had a brightness of about 85, whereas that from a second hour of grind on remaining oversize had a brightness of about 88. On the same sample, minus 100-mesh from head samples gave 81 brightness compared to 86.5 on a bulk grind.

Beneficiation was aimed chiefly at removing phlogopits because it had a relatively low brightness. A small improvement was obtained with dry trials. Further improvement was realized from wet tabling followed by grinding and screening of the table product. This could be more expensive than the operation would be worth.

Probably, the best answer to this beneficiation problem will involve the simplest of processing, such as dry grinding and fine cut-point air classification, with a screen, or air table, to remove some of the mica from coarse being returned to the grinding unit. This would avoid the drying requirement of wet processing.

The work performed relates only to the three head samples provided and covers only equipment available in the Industrial Minerals Milling Section of the Mineral Processing Division. Advantages which might be gained from shape factors, Table 24, tend to be negated by hardness factors and relatively slight specific gravity differences.

TABLE 24

Factors Relating to Minerals in Deposit

Mineral	Amount(%)	Sp gr	Hardness	Shape
Tremolite	40-50	2.9-3.2	5-6	Acicular
Phlogopite	30-35	2.8-2.85	2.5-3.0	Tabular
Quartz	20-25	2.66	7	Angular