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HIGHLIGHTS OF TEST WORK PERFORMED ON A KYANITE-BEARING GNEISS FROM THE SUDBURY PROPERTY OF NORTHERN KYANITE MINES LIMITED: PREPARED AS A GUIDE IN DEVELOPING A COMMERCIAL FLOW SHEET.

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Note: This report relates essentially to the samples as received. It shall not, nor any correspondence connected therewith, be used in part or in full as publicity or advertising matter.

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Highlights of Test Work Performed on a Kyanite-bearing Gneiss from the Sudbury Property of Northern Kyanite Mines Limited: Prepared as a Guide in Developing a Commercial Flow Sheet.

A great deal of work has been done on material from this deposit over the past five or more years. Several reports have been issued, the most recent being IM 189 which dealt with the flotation of feed which had received prior beneficiation by magnetic separation. The system described in this report was effective but expensive, particularly for capital cost. Efforts since that time have been directed toward devising other recovery methods, equally effective but less costly.

The investigation has been continually hampered by the necessity to produce kyanite concentrates in considerable bulk, both for ceramic investigation and for market research. As each new requirement for concentrates came up the best current means available was applied, and so far as possible experimentation with the pilot plant procedure was carried out. A great deal of information has been obtained and it is the purpose of this report to present the most important facts in some order as a guide in building up a commercial flow sheet.

Tests performed with a few pounds of material are presented as "Laboratory", while treatment of bulk lots of up to 5000 lbs is presented as "Pilot Plant" work.

Description of Material

The material contains up to 40% biotite which poses a problem in removal. Above 28 mesh kyanite particles may have some attached biotite. The liberation point is therefore considered to be 28 mesh. The other minerals present, garnet, quartz and feldspar all appear to be separated from the kyanite at above 28 mesh. Kyanite, garnet and biotite have higher specific gravity than quartz and feldspar. Garnet may be isolated fairly easily as a by-product.

In comminution kyanite is resistant and there is notable concentration in the coarser size fractions. To illustrate, TABLE 1 shows distribution of kyanite and particle size for material subjected to a standard crushing procedure through 4 mesh.

TABLE I

Fraction	Weight %	% Kyanite	% Distribution
-4 + 10	34.0	25.0	42.0
-10 + 65	49.7	21.8	53.5
-65 + 100	5.4	4.21	1.1
-100	10.9	6.36	3.4
	100.0		100.0

The percent kyanite in -100 mesh is frequently lower than above. In this case -65 mesh might be discarded to give a weight reduction of 16.3% for a 4.5% loss in kyanite.

The kyanite itself tends to break into needles, a part of which will pass a screen actually smaller than the average particle size. For example, in a sample screened on 35 mesh particles of 0.02 inch diameter but of 0.04-0.05 length will often pass the screen. In tabling, on the other hand, the particles tend to move with their long dimension parallel to the deck.

During comminution the biotite breaks up into flakes of various sizes, the largest of which may be screened out. Garnet, quartz and feldspar assume more equidimensional shapes.

Laboratory Tests.

Up to about 10% of the biotite content may be removed on scalping screens during comminution. Jigging, classification, gravity devices, and flotation, are all partially effective in eliminating the rest, but invariably magnetic separation must be applied for final stripping of biotite from kyanite.

As biotite is troublesome in kyanite flotation a number of trials were made with jigs, tables, and classifiers to effect its removal from float feed. While each of these was partially successful one consideration or another rendered all but one or two impractical. TABLE 2 serves to indicate the type of result obtained.

TABLE II

Machine	Bi Conc. (%)	Ky. Loss (%)
Jig	73	4.6
Wet table	38	8.2
Air table	100	0.0
Classifier	88	2.7

With the air table a cut which is virtually all biotite may be made, but as shown below this device proved more useful when used for other purposes.

Of the classification devices tried a Denver Centrifugal (or Cone) proved best and produced the above result. Its capacity was, however, very low and in pilot-plant work a Denver Hydroclassifier was used fairly successfully.

Various attempts were made to take advantage of the factors of differential grind, specific gravity, and particle shape. Air jigging was thought to be a prospect, either on -4 mesh as crushed, or on the -4 + 10 mesh fraction (-10 being suitable for air tabling as shown below). This has the advantage of dry treatment on comparatively coarse material. Air jigging the as crushed -4 mesh tended to give a good size separation without too effective bulk reduction at low kyanite loss. At a bulk reduction of 5.6% a kyanite loss of 2.4% was sustained. For a 25.6% bulk reduction 9.9% of the kyanite was lost. Beyond this point kyanite losses were excessive. Using the -4 + 10 mesh fraction trials varied through a wide range of bulk reductions, the best result being at 13.3% where 5.9% of the kyanite was lost.

Although air jigging the -4 mesh crusher product, or the -4+10 mesh fraction, did not show any great merit heavy liquid separation indicates that a considerable concentration should be possible at -4 mesh with reasonable losses. Specifically, some -4+10 mesh placed in 2.96 SG liquid gave a 47% by weight sink which contained 45% kyanite, while the float, 53%, contained 2.4% kyanite. Removal of the 53% weight would, therefore, represent a loss of only 6% of the kyanite. Air tabling the -4+10 mesh may be more effective than air jigging. One test only was done and this gave a tailing representing 30% of the bulk which did not appear to contain much kyanite (no assays were done). While tests so far completed are not too promising it appears that some concentration at -4+10 mesh should be possible.

An integrated trial was also made using the Whippet Air Table and screens to see if a portion of the kyanite could be won quickly by this comparatively simple means.

The test lot was ground through 14 mesh and separated into five screen fractions. The coarsest was passed over the Whippet and three products were collected, concentrates, middlings and tails. The concentrates went directly to magnetic separation, the tails to waste, and the middlings to regrinding. Reground middlings were then sized, the various fractions being added to the original fractions of corresponding size. This pattern was repeated through each succeeding size until the entire lot had been worked. Cut points on the table were selected by eye. Figure 1 shows weight distribution and results obtained from this test. It is believed the tailings assay obtained is high which would indicate lower loss with correspondingly higher recovery. The material handled in Cycle 5, -65 mesh, was low in initial grade, 10.2% kyanite, and comparatively fine for successful air tabling. As indicated, this material was only concentrated to 27.8% kyanite, but the product was excellent float feed because much of the biotite had been eliminated.

Quite a number of laboratory flotation trials were made, particularly for direct fatty acid flotation of kyanite in basic circuits. The culmination of this work is shown in the three tests outlined by TABLE III. It is not necessary here to trace the variations leading to this conclusion. The system is the simplest evolved and is as effective as more complex ones.

Figure 1

FLOW DATA FOR WHIPPET TEST
(all figures in grams except % Kyanite)

	Tails	Mids	Concentrate Weight	Concentrate Mags	Concentrate Non Mags
Cycle 1	(Feed -14+20M = 3470)				
	670	1660 (Reground)	1140	215	921 (93.9% Ky)
Cycle 2	(Feed -20+28 = 4874)				
	823	2816 (Reground)	1235	305	925 (91.8% Ky)
Cycle 3	(Feed -28+35 = 9136				
	1192	6091 (Reground)	1853	528	1320 (90.7% Ky)
Cycle 4	(Feed -35+65 = 9795)				
	3455	3940 (Reground)	2400	343	2045 (42.1% Ky)
Cycle 5	(Feed -65 = 9019)				
	3907	3127	1985 (27.8% Ky)		
	10,047=Tails	3127=Mids	1391 = Mags		

	Weight (gms)	% Kyanite	% Distribution
Concentrate = (Product 1,2 & 3	3166	92.0	56.8%
Float Feed (Product 4 & 5)	4030	35.0	27.7%
Discard (Tails + Mids + Mags)	14,560	5.46	15.5%
			100.0%

TABLE III

(Feed Deslimed Each Test)

Test No.	54	55	56
Feed Size (mesh)	-28	-28	-35
% Solids	30	28	30
Water	Dist.	Dist.	Tap
Temp. (°C)	27	27	27
pH	8.9	7.0	8.0
Na_2SiO_3(H/T)	0.2	0	0.2
Cond. (min.)	2	0	0
Fatty Acid	1.0	1.0	1.0
Cond. (min.)	2	2	2
R. Float (min.)	4	4	4
Cl 1 " (")	3	3	3
Cl 2 " (")	3	3	3
Cl 3 " (")	3		
Slimes (% Ky)	0.54	1.42	
R. Tails (% Ky)	4.02	6.25	
Cl 1 " (")	9.44	23.9	
Cl 2 " (")	20.2	38.0	
Cl 3 " (")	37.2		
Mags (")	11.5	12.7	
Conc. (")	95.4	94.5	95.2
Recovery (%)	76.9	69.3	73.9

No. 56 was done rather hurriedly to see if soft water would be necessary in a pilot plant run and intermediate assays were not obtained. Use of Ottawa tap water does not have a serious effect, but dropping the Na_2SiO_3 altogether does not appear advisable.

It should be pointed out that longer conditioning does not greatly effect results. These tests were run at comparatively high density but under batch control. In continuous operations high density resulted in downgrading and "sanding" trouble. Half or less the above density proved best for continuous runs. In batch tests the bulk of the kyanite floated fairly quickly but coarse particles continued to float over a 15-20 minute period. In this way tails could be stripped to 1-2% kyanite rather than the 4-5% resulting from short floats. In continuous operation the long scalping time is not practical, and in pilot plant work the rougher tails produced were generally higher in kyanite than those of batch tests. In pilot plant runs, therefore, the practice was to scavenge primary circuit rougher tails for recovery of a low grade (i.e. 70-90% Ky) concentrate as blending stock.

Early in the laboratory testing a system was developed which was dubbed "The 4-stage system". This produced good results although it is more complex than the foregoing. It is felt some record of this work might be helpful here. The four stages are: (1) Feed preparation, i.e., comminution with removal of biotite by screening and classification. (2) Bulk float of gangue with amine. (3) Fatty acid flotation of kyanite from amine circuit tails. (4) Magnetic separation of float concentrates. The best result obtained from the test series employing this system is given in the following sequence.

Note that damp kyanite in contact with iron becomes stained, hence the removal of mill filings by ferrofilter.

A. Preparation. Feed crushed through 4-mesh then ground in a rod mill in closed circuit with a screen and classifier. Coarse biotite was removed on the screen upper deck and -48 mesh float feed was removed as undersize from the lower deck. The +48 mesh was classified to remove biotite then returned to the mill The -48 mesh float feed was run through a ferrofilter.

TABLE IV.

Fraction	Wt. %	% Kyanite	Distribution
Screen O'size	6.4	4.6	1.3
Class. O'flo	15.9	2.8	3.9
Mags	1.3	18.7	0.9
Float Feed	76.4	28.4	93.9
	100.0		100.0

B. Amine Circuit. Flotation at 18% solids as shown below: (Tails washed and dewatered in classifier.)

TABLE V

Test No.	47 (b)	Wt. %	% Dist.
Water	distilled		
Na_2CO_3 (H/T)	1.0		
Cond. (min.)	0		
Dextrin (H/T)	0.5		
Cond. (min.)	2		
ARMAC-T (H/T)	0.5		
Pine oil (H/T)	0.02		
Cond. (Min.)	2		
Temp. (°C)	27		
pH	9.4		
Float Time (min.)	2		
Class. O'flow (% Ky)	57.6	1.8	3.8
Conc. (% Ky)	2.2	51.1	4.1
Tails (% Ky)	52.8	47.1	92.1
			100.0

C: Fatty Acid Circuit. Washed amine circuit tails floated as shown below:

TABLE VI

Test No.	47 (b)	Wt. %	% Dist.
Water	Dist.		
Na_2CO_3 (H/T)	0.5		
Na_2SiO_3 (H/T)	0.2		
Cond. (min.)	2		
Fatty Acid (H/T)	1.5		
Cond. (min.)	2		
Temp. (°C)	27		
pH	9.0		
R. Float (min.)	8		
Cl 1 " "	4		
Cl 2 " "	3		
Cl 3 " "	3		
R. Tails (% Ky)	2.6	1.7	0.1
Cl 1 " "	8.5	29.3	4.7
Cl 2 " "	40.9	3.8	3.0
Conc. "	74.7	65.2	92.2
			100.0

D. <u>Magnetic Separation</u>: Conc. dried and run over magnetic separator with results given below.

TABLE <u>VII</u>

Test 47 (b)	Wt. %	% Ky.	% Distribution
Magnetics (%)	23.0	0.8	0.2
Conc. (%)	77.0	96.8	99.8

Overall Recovery: Recovery A = 93.9%

" B of A = 92.1% of 93.9% = 86.5%

" C of B = 92.2% of 86.5% = 79.7%

" D of C = 99.8% of 79.7% = <u>79.6%</u> at <u>96.8%</u> Ky.

<u>Pilot Plant Runs</u>

During the past 4 years over two tons of kyanite concentrates of 95% grade have been produced for ceramic investigations and for work in research. During the pilot-plant-type operations by which these concentrates were made, as much experimentation as possible was carried out. Such experimentation was guided by the laboratory work, and also by results obtained from the pilot plant operations themselves.

The largest body of pilot plant work consisted of flotation, with gravity methods, either in feed preparation or scavenging of float tailings, accounting for much of the rest. Magnetic separation is pretty well essential in finishing the concentrates. Such parts of this work as appear to contribute useful information are included herein.

Because air table trials with the laboratory Whippet machine were encouraging, the larger Kipp-Kelley air table was used as the first operation in the most recent pilot plant run. Best use of this machine has probably not been outlined, however, results were again encouraging with about 50% recovery of 95% kyanite. Flow arrangement for this larger lot was somewhat different from that used for the Whippet trial, and is shown, together with the kyanite content of various products, in Figure 2. The initial step was, of course, to grind the full 5000 pounds through 10 mesh. This was in turn separated into -10+35, -35+65, -65+100 and -100 mesh fractions. The -100 mesh was low enough in kyanite to be discarded. The -65+100 mesh was routed directly to flotation. The other two were treated as shown. Air table cuts were made by eye, and products estimated to be grade material were finished on the Dings Magnetic Separator. Some good grade material with inclusions was routed to flotation.

Figure 2

Flow Data For Kipp-Kelley Run

C = Conc. T = Tails. F = Float Feed. M = Magnetics
(Figures are % kyanite)

Run No. 1: (Feed = -10+35 mesh)

(Split No.)	5	4	3	2	1
	Biotite	Run 3	Run 2	C 98.1 / M	C 99.8 / M

M from splits 2 and 1 combined: F 96.6, M

Run No. 2: Sample 3 screened on 20 and 30 mesh.

Feed = (+20 mesh)

5	4	3	2 + 1
F	F	F	C
36.5	54.3	80.5	95.9

Feed = (-20 + 30 mesh)

5	4	3	2 + 1
T	F	F	C / M
8.8	25.6	89.6	97.7

Feed = (-30 mesh)

5	4	3	2 + 1
F	F	F	C
34.6	83.4	90.0	97.6

Run No. 3: Sample 4 screened on 20 + 30 mesh.

Feed = (+20)

5	4	3	2	1
T	T	T	F	F
4.1	6.4	17.3	37.3	87.5

Feed = (-20 + 30)

5	4	3	2	1
T	T	T	F	F
3.7	8.2	9.9	30.6	63.6

Feed = (-30 mesh)

5	4	3	2	1
T	T	T	F	F
6.7	11.9	17.1	38.6	54.0

Fifteen products were combined as float feed and ground through 35 mesh. Plus 35 mesh remaining after grind was tabled.

Run No. 4: Feed = (+35 mesh)

	5 T	4 T	3 C	2 C	1 T
	Biotite	7.0	68.3	99.3	Garnet

Run No. 5: Feed =(-35 + 65)

	5 T	4 T	3 F	2 and 1 C
	Biotite	7.0	30.0	97.7

Eight products from the tabling were high grade concentrates either direct or with some magnetic separation as shown in summary below:

TABLE VIII

Sample	Weight (lbs)	% Kyanite	Recovery (% of Ky. in Feed)
Run 1:1	14.5	99.8	1.4
Run 1:2	235.0	98.1	21.8
Run 2:+20	29.0	95.9	2.7
Run 2:-20+30	32.5	97.7	3.1
Run 2:-30	3.0	97.6	0.2
Run 4:2	38.0	99.3	3.6
Run 4:3	55.5	68.3	3.6
Run 5: 1+2	137.0	97.7	13.1
Totals	544.5	94.5	49.5

Table conc. = 545 lbs or 11% of original feed
Table & Magnetic Tailings = 2850 lbs or 57% of original feed
Float Feed = 1600 lbs or 32% of original feed

11% + 57% + 32% = 100% of original feed

An analysis of the float feed indicated a kyanite content of 26.6%, the biotite in particular having been reduced by the air tabling. Moreover this feed was well sized between 35 and 100 mesh, with some -100 mesh present as developed in secondary grinding of the table products routed to float feed. The primary flotation circuit consisted of roughers plus three cleaning stages. Feed was pulped with warm water and pumped to a conditioner. Sodium silicate at 0.2 pounds per ton was added to the pump and Oleic Acid at the rate of 2.0 pounds per ton to the conditioner. Volume of the conditioner produced an average holding time of 18 minutes, although much less than this would have been acceptable. Rougher float was at 12% solids and the pulp temperature 25°C. Froth was washed into the 1st cleaner, and subsequently into the 2nd and 3rd cleaners, with cold water to give cleaner floats at approximately 10°C and 10% solids. Third cleaner concentrates were filtered and dried as product. The cleaner tails were bulked as middlings and the rougher tails were routed to scavenging. Flotation results are given below:

TABLE IX

	Weight (lbs)	% Kyanite	% Distribution
Primary feed	1600	26.6	100
" conc.	292	79.0	54
Scavenger feed		10.3	
" conc.	218	48.0	25
Final tails		4.8	
Losses (Tails & Mids.)			21

Flotation products were cleaned up by magnetic separation with the following results.

TABLE X

	Weight (lbs)	% Kyanite	% Distribution
Primary Conc.	208	95	59
Scavenger "	135	68	27
Magnetic Tails	167	28	14
			100

All work done as part of the last pilot plant run has been summarized below.

TABLE XI

	% Kyanite	% Distribution
(1) Original 5000 lb lot	21.0	100.0
(2) Table concentrate	94.5	49.5
(3) Primary Float concentrate	95.0	17.1
(4) Scavenger " "	68.0	8.8
(5) Table waste (tails + mags)	2.6	7.1
(6) Float " (mids + tails)	12.6	13.1
(7) " " (mags)	28.0	4.4
Combined High grade (2+3)	94.6	66.6
" Product (2+3+4)	91.5	75.4

As illustrative of the type of variation tried during pilot plant flotation operations, Table XII has been assembled.

TABLE XII

Variation	Effect
Feed Preparation	Humphreys spirals effective, tables good, for reducing biotite in feed.
Desliming	Hydroclassifier best
Feed rate	3 lb/min. (or 200 lb/hr) best for this equipment.
Density	10-15% best; up to 20% tolerable.
Oleic acid	1-2 lb/ton depending on brand.
" " steps	Some recovery improvement.
Pine oil	Increases float, lowers grade badly.
Circuit	Rougher and three cleaners best.
Temperature, Roughers	25-30°C best. Fair down to 18°C.
" , Cleaners	Any. Cold water okay.
Mids, Recirculation	Recovery increases, grade drops sharply.
" Refloat	Very poor grades
Scavenging	Flotation, Humphrey's spirals and tables all fairly effective.
Mag. Separation, Dry	Close sizing of feed helps.
" " , Wet	High recovery with Jones machine.

Some of the above may be usefully elaborated upon, for example, the use of wet grinding methods followed by a gravity device to improve the feed to flotation. A number of such trials indicated that the Humphrey's spiral was the most useful device. Light drawing will give concentrates of up to 44% kyanite but with 25% loss; weight of material passing to flotation is, however, reduced by 62%. This can be varied to the point of drawing heavily, to reduce weight of material passing to flotation by 10%, with a kyanite loss of less than 1%. The latter has an advantage in reduced bulk to flotation, particularly biotite, but the grade of float feed is very little improved. Flotation on such feed produced an indicated primary recovery of 67% at 60% kyanite grade (or a magnetic separator concentrate representing 57.5 recovery at 93.7% grade.) Scavenging produced another 10.9% recovery of 54% kyanite product.

There appears to be an optimum range for Oleic Acid. If too little is used froth volume is very small, with consequent low recovery, and there is a tendency for more biotite to float. On the other hand too much Oleic will produce addquate froth but at the same time lowers the grade of product notably. Possibly additional cleaners would compensate.

Adding a little extra Oleic to the second half of the roughers may be helpful but does not appear to increase the rather dull forthing. A test, however, produced 10% more concentrate and slightly lower % Ky. in tails assay. It was observed in the batch flotation that coarser kyanite particles would float slowly, over some period of time, after the first dense froth was cleared. Failure to get the second half of the roughers pulling well in pilot plant flotation is thought to partly account for the high tails assay (i.e., 8-10% kyanite). Possibly a short conditioning with a little extra oleic acid would do it, or a different type of cell (e.g. for 1 test tails were run into a single large Denver cell for scavenging. No extra Oleic acid was added but a voluminous froth was obtained.)

A drop or two of pine oil was tried both at the head of the rougher circuit, and half way down it. Rougher froth volume increased sharply in either case, but much of it was due to floating biotite. Similarly, pine oil added to cleaners improved volume floated but sharply reduced grades.

Recirculation of middlings was tried in various ways. The best success was obtained by joining the three cleaner tails stream and feeding them through a Denver Cone Classifier. The underflow was returned to the rougher circuit and the overflow wasted. In two trials with this set-up, indicated recovery was around 80% but the concentrate was dark with biotite. After magnetic separation recovery was cut to about half and concentrate grade averaged 90% kyanite.

Refloating the mids in a side circuit with no additional reagents again yielded a heavy dark froth. This assayed at 38% kyanite after three cleanings, while the tails ran 19% kyanite.

Three methods of scavenging primary float tails were tried (1) Scavenger flotation, (2) Humphrey's spiral, and (3) wet tabling. Of these the Humphrey's spiral was possibly the most practical for first cost and space considerations, but it produced the poorest overall results. Further work with this device might, however, effect improvements - it proved quite versatile on feed. Flotation was the scavenging system generally used, and on the average this produced concentrates of comparatively coarse kyanite running 65-85% after magnetic separation. Tails assays ranged from 4-6%. Tabling was probably the most effective of the three systems as it produced a comparatively biotite-free concentrate of rather coarse particle size. For example, one trial using a diagonal deck table, produced a 44% kyanite concentrate with a 3% tail from feed of 9% kyanite. Recovery was 70%. The concentrate was sized at 65 mesh, the +65 cleaning up on the magnetic separator at 95.3% Kyanite, and the -65 at 82.9% Ky. The +65 magnetic mids ran 72.3% Ky. Chief drawback to this method is the number of tables required.

As indicated above, overall recovery by dry magnetic separation was improved by sizing of the feed. Various trials were made. Up to 28 mesh the coarser the size the sharper the dry magnetic separation. Conversely, the finer the poorer. The -100 mesh may be worked to quite good concentrates, but with very high loss of values to magnetics. This problem is reduced by wet magnetic separation in a Jones machine. The Jones equipment makes effective separations of weakly magnetic materials in the very finest sizes.

As a test of the Jones machine some +28 mesh concentrates, composed of kyanite with biotite inclusions, were crushed and cleaned on the Dings separator to obtain a very high grade concentrate and the usual magnetic reject which normally has to be discarded. This reject was all -28 mesh and contained 53% -325 mesh. The Jones machine recovered 65% of this sample as high grade kyanite.

The Jones Magnetic Separator would obviously have several advantages in kyanite working, particularly in the finishing of flotation concentrates. Feed to flotation could be considerably finer than the -35 generally used, and the concentrates could be cleaned before the drying stage with resultant reduction in bulk.

In preparing flotation feed for the pilot plant a compromise was made between flotation efficiency and dry magnetic separator efficiency. Better flotation results may be obtained at -48 or -65 mesh than -35 mesh, but magnetic separation losses are greatly increased with the finer products. To illustrate this, three selected batch test results are given below, as Table XIII.

TABLE XIII

Feed Size (Mesh)	Float Concentrate		Mag. Sep. Concentrate	
	Recovery %	Grade %	Recovery %	Grade %
-48	89.4	68.1	80.1	94.3
-35	80.7	79.7	77.5	94.1
-28	79.6	76.5	76.9	95.4

Grinding to nominal 35 mesh actually produces an approximately -28 mesh product as explained earlier, but usually also produces a good deal of fines. A typical grind is shown in Table 14.

TABLE XIV

Size	Weight %	% Kyanite
-35+65	52.1	22.7
-65+100	17.4	21.3
-100+200	19.9	10.2
-100	10.6	12.7

Flotation from such a feed tends to result in a concentrate of finer size distribution than the above because the coarser particles of kyanite are the ones which fail to float readily and therefore remain in rougher tails. The finer particles on the other hand end up in the concentrates.

Most of the flotation pilot plant runs produced high grade finished products with comparative ease although final recoveries were generally lower than anticipated, i.e. 40-70%. A record of one of the more successful runs is given as Table XV.

TABLE XV

Feed: -35 mesh, rod mill grind
Circuit: Hydroclassifier, pump, conditioner, 6-cell Fagergren Rougher; 3 - 2 cell Denver Cleaners, filter, drier, magnetic separator. Cleaner tails bulked. Rougher tails scavenged. Duration of run, 5 hours.

Reagents: Na_2SiO_3 to pump 0.2 lb/ton. Oleic acid to conditioner 1.5 lb/ton. Warm tap water to roughers, cold to cleaners.

Product	Weight (lbs)	% Kyanite	% Distribution
Primary			
Feed (-35 M)	3 lbs/min	21.0	100.0
R. Tails		9.01	
Cl 1 & 2 Tails		23.5	
Cl 3 Tails	41	55.1	11.9
Conc.	128	74.2	50.2
Cl 3 T Mags	22		
" " Non-mags	19	92.3	9.3
Conc. Mags	31		
" Non-mags	96	96.2	48.8
Scavenger			
Feed	3 lbs/min.	9.01	
Tails		4.71	
Mids.		18.9	
Conc.	59.6	56.5	17.8
" Mags.	28.2		
" Non-mags.	31.0	88.9	14.6
Blended Products			
Pr. C. Non-mags) Pr. Cl 3 " "	115	95.5	58.1
Above + Scav.	146	94.2	72.7

Flow Sheet Suggestions

The following suggestions are offered for consideration in the planning of a basic flow sheet for this material. They are derived from a study of test results coupled with considerable experience in working kyanite gneiss.

(1) Crushing Section: Jaw followed by cone crusher to produce nominal 4 mesh. Cone in closed circuit with double deck screen, having 1/2 or 3/8 inch top for biotite scalping, and 4 mesh lower for finishing.

(2) Dry Gravity Section: Rescreen -4 mesh on a 10 upper, 48 lower double deck screen. Treat -4+10 by some gravity method such as air jig, air table, or even heavy media separation, to obtain waste and a concentrate for regrind, possibly with rolls, and return to the 10-48 mesh primary. Route -10+48 to a 28 mesh screen with +28 going to one air table and -28 to another. Both tables would produce waste, middlings and concentrates, the middlings to be reground, possibly with rolls, and returned to the 10-48 mesh primary screen. The concentrate could be combined, or treated separately, on dry magnetic separators with production of finished product and magnetic tails. The magnetic tails could be reground, wet, for scavenging in a Jones wet magnetic separator.

(3) Flotation: Primary screen -48 mesh first deslimed, then pulped with warm water plus about 0.2 pound per ton of Na_2SiO_3. A short conditioning time with 1-1½ pounds per ton good fatty acid (e.g. W.C. Hardesty Co. Harfat 231 has proved more selective at lower input than most brands), followed by roughing and two or three cleanings - cold water is satisfactory for cleaning. Pulp

density should probably be kept below 20% solids. It should be possible to recover 70-80% of the values and waste all tailings. It might possibly be necessary to scavenge rougher tails in a separate circuit. The concentrates should be passed through a Jones magnetic separator with the magnetics wasted and the product dried. It might be advisable to consider passing all flotation feed through a Jones machine instead of using it on concentrates only.

Crushing and dry gravity sections could be brought into operation quickly with flotation following when ready.