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A Preliminary Study of the Benefication of Montana Kyanite

Donald Paul McCarthy

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A PRELIMINARY STUDY OF THE BENEFICIATION OF MONTANA KYANITE

A Thesis
Presented to
The Department of Mineral Dressing
Montana State School of Mines

In Partial Fulfillment
of the Requirements for the Degree
Bachelor of Science in Metallurgical Engineering

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INTRODUCTION

This investigation is a preliminary study of the beneficiation of Montana kyanite, and while preliminary in degree the information gained may serve as a guide for the eventual exploitation of this Montana resource. No production of kyanite from Montana has ever been recorded. Yet the demand for industrial minerals such as kyanite has rapidly increased in the first part of the 20th Century. Initial mining of all industrial minerals has followed a pattern of exploitation of the richest deposits first, and leaving the less profitable materials for later generations. Fortunately, the technical knowledge required to profitably process these lower-grade deposits is growing; and, forced by strategic necessity, deposits formerly considered worthless, now represent a potential worthy of consideration. Thus, utilization of Montana kyanite will eventually be necessary. It is hoped that this investigation may in a small way expand the reserves of kyanite by suggesting methods of separating this mineral from the associated mineral constituents.

STRATEGIC KYANITE

Recent Senate Investigation of the state of our natural resources has produced a list, approved by the Army-Navy

Munitions Board, of materials of strategic and critical importance for which stock-piling is recommended to ensure adequate supply for future emergency. Indian kyanite is represented in that group.[1]

From an economic and military standpoint, an adequate domestic supply of kyanite would be advantageous. The very real possibility that research into beneficiation of domestic deposits may contribute to a better domestic supply is certainly worthy of consideration. Research into beneficiation alone is, of course, not sufficient. Thorough geological exploration may be done concurrently. In addition, the users of foreign kyanite may be required to change their manufacturing specifications in order that domestic materials can be substituted. For example, it appears that to use domestic kyanite a less coarse product must be considered. Surely, these considerations merit investigation.

BENEFICIATION OF KYANITE IN THE UNITED STATES

During the course of the past twenty years, there have been many studies into beneficiation of domestic kyanite with some modicum of success. One or another process of separation of the kyanite has been adopted and mills have been established mainly in the southeastern part of the United States. The Celo Mines employs air tables and magnetic separators.[2]

1. Super-numerals refer to Bibliography, page 25

Kyanite Products Corporation has adopted a scheme using 'fatty-acid' flotation.[3] An unusual method of liberation used by the Vitrefrax Corporation at Oglesby, California, may bear mentioning here: The ore is heated in a rotary kiln, it drops directly into water. Quartz gangue is shattered loose as it converts rapidly from the beta to alpha form with attendant contraction. The iron having been reduced to magnetic condition is removed by magnetic separation.[4] Furthermore, kyanite has been separated by placer mining methods in Georgia.[5] Thus the importance of beneficiation to kyanite is illustrated.

PHYSICAL AND CHEMICAL PROPERTIES

A thorough knowledge of the physical and chemical properties is often critically important to the beneficiation of industrial minerals such as kyanite. For this reason these properties are reviewed:

Composition	$Al_2O_3.SiO_2$
Indices of Refraction	alpha: 1.717
	beta: 1.722
	gamma: 1.729
Optical Character	Negative
Crystal System	Triclinic
Habit	Blades
Cleavage	(100) Very perfect

	(010) Less perfect
	(001) Parting
Hardness	4 parallel to length, 7 parallel to width
Specific gravity	3.6
True Optical Angle	82°
Luster	Vitreous to pearly
Color	Blue, white, blue along the center of the blades with white margins; also gray, green and black. Translucent to transparent.[6]

Kyanite, first described by Saussure in 1796[7], is grouped with dumortierite, andalusite, and sillimanite, from which it differs only in crystallographic form. It has the property, in common with other members of the sillimanite group, of converting to a mixture of mullite ($3Al_2O_3 \cdot 2SiO_2$) and glass when heated to about 1300°C. The extremely high refractoriness of the resulting mullite is a key to the industrial importance of kyanite.

GEOLOGICAL OCCURRENCE

Kyanite occurs in metamorphic areas principally in gneiss and mica schist, in lenses in pegmatite dikes, distributed through quartz veins or quartzitic masses, or in residual clays resulting from weathering of gneiss or schist. It is formed under conditions of high temperature and pressure by metamorphism and recrystallization of aluminous members of a stratified series, or by pneumatolytic deposition.[8]

WORLD DISTRIBUTION

Kyanite is found in the United States in Georgia, North Carolina, Virginia, Maryland, Pennsylvania, Wyoming, Washington, California, and Montana. Foreign deposits are located in Russia, Czechoslovakia, Austria, Italy, Switzerland, France, and in India (most important foreign source).

MONTANA KYANITE

The Montana deposit of kyanite with which this investigation deals is located about ten miles south of Ennis, Montana (hereinafter referred to as the Ennis Deposit) on the western bench of the Madison River valley in the foothills of the Gravelly Range. The earliest record of this occurrence was made by J.J.Runner in 1928.[9] C.L. Nordstrom studied the geology of the deposit in the spring of 1947.[10]

The stratigraphy of the Ennis Deposit is relatively simple. The Cherry Creek Complex of Algonkian Age is the basal. This is overlain unconformably on the west by Paleozoic strata of Cambrian Age. Cenozoic sediments outcrop to the east. Pegmatites are intruded into the Cherry Creek only. These pegmatites are of two types: 1) Quartz and 2) Feldspathic.

The geologic structure is more complex. The Cherry Creek has been intensely folded, faulted and tilted; the Paleozoic formations are deformed to a much lesser extent.

The occurrence of the kyanite is of two forms: 1) as disseminated crystals in the mica schist of the Cherry Creek Complex, and 2) as massive crossbladed crystals in the quartz pegmatites. The mica schist, referring to the first type of occurrence, is a medium grained even textured rock with the following mineralogic composition:[10]

Biotite.	.30%
Quartz	.20
Orthoclase.	.10
Plagioclase	.15
Garnet	5 to 10
Kyanite and Sillimenite	5 to 7
Accessory minerals Tormaline, Hornblende and Magnetite.	.10

In the quartz pegmatite, the kyanite is coarse-grained. A typical composition is:

Kyanite.	.30%
Sillimanite	.30
Quartz	.25
Feldspars	.10
Accessory Minerals Graphite, Tourmaline, Magnetite	5

ECONOMIC FACTORS

The most recent production figures available are for the year 1946. Imports and consumption figures are taken from the Minor Non-Metals section of Minerals Yearbook, 1946. (See Table No. 1) Exports in 1945 and 1946 were small; 307 tons in 1945, 342 tons in 1946. The markets were Canada, Mexico, Argentina, Brazil, Nicaragua, Netherlands, China, and the United Kingdom. Value of 1946 exports was $17,881.00. Domestic production is not sold on the open market; therefore, no production figures are available.[19]

The state of the world's reserves of kyanite is not determinable on the meager exploration information available. In fact, there are no estimates of our domestic reserves aside from the general description of the schist occurrence in the Southeast that mentions very extensive outcrops of disseminated kyanite. With regard to the Ennis Deposit, further development work is needed to determine the vertical extent and the possible horizontal continuation.

Current prices (March 1948) of kyanite are variously reported as from $85.00 to $95.00 per ton for low iron content 10-mesh material. Calcined, grain, 10 mesh $95.00 to $105.00 per ton.[11] Crude material, f.o.b. point of shipment commands $19.00 per ton; -35 mesh $37.50, per ton; glass grade $48.00 per ton.[12] The price of India Kyanite f.o.b.

Atlantic seaports in 1946 was about $22.00 per ton.[19]

	IMPORTS		CONSUMPTION SHORT TONS	STOCKS DEC.31 SHORT T.
	SHORT TONS	VALUE		
British East Africa	395	3,308	Not Avail.	Not Avail.
India	10,110	109,990	" "	" "
Union of So. Africa	277	3,187	" "	" "
	10,782	116,485	11,500	7,280

TABLE NO. 1. Consumption and stocks of imported kyanite in the United States, 1946.[19]

USES

At PCE cone 12 to 13 (1310°C. to 1350°C.), kyanite expands to a mixture of mullite and cristobalite with a corresponding reduction in specific gravity to 3.1. Therefore, it is calcined to mullite before being fabricated. Characteristics of mullite refractories may be summed up as follows:

1) High softening temperature, PCE of 38 (1835°C.)
2) Ability to bear high loads at elevated temperatures.
3) Volume stability at high temperatures.
4) Thermal shock resistance.
5) Comparative ease of installation.

The former specification that kyanite be marketed relatively coarse has been superceded because the necessary calcination reduces it to a fine friable form. Most industrial uses require that calcined kyanite pass a 100 mesh sieve and for some purposes, the kyanite is required to be substantially minus 325 mesh.

Metallurgical industries account for 50% of the total kyanite refractories used in the United States. This refractory material is used in induction furnaces for melting of high copper brasses. It is used for plungers, rings, feeders, etc., in glass manufacture; and as kiln furniture in the ceramic industry.[13] Insulating refractories may be fabricated from kyanite, clay and sawdust.[14] Presently spark-plug porcelain is made from andalusite and dumortierite. Undoubtedly kyanite could be so used.

Recent investigations have been conducted to determine the practicability of installing kyanite refractores in boiler furnaces on naval vessels.[1]

SURVEY OF KYANITE BENEFICIATION

The relatively high specific gravity of kyanite (3.6), would lead one to conclude that gravity concentration might yield a satisfactory product. However, the platy acicular character of the crystals negate, to a large degree, the advantage of greater specific gravity. (See for example, references 15, 16, 17, 18). While being capable of eliminating a large percentage of the gangue, these methods usually can not produce a concentrate of better than 80 percent. Heavy minerals such as garnet and tourmaline are not removed by gravity methods.

Flotation methods have proved very satisfactory in many instances. The favorite procedure has been to obtain a rougher concentrate by use of sodium oleate and/or oleic acid as collector with pine oil as the frother. The rougher then is cleaned by a flotation operation using sodium silicate as dispersant. The final cleaned concentrate reportedly assays about 98 percent kyanite. [16, 3]

INVESTIGATIONAL PROCEDURE

Beneficiation studies on the Montana kyanite logically fall into the following sequence: identification of the minerals, preparation of the material, and methods of separation.

Minerals. The following minerals were identified, and these minerals are listed in table No. 2 in order of their relative abundance.

The following mineralogical association could only occur in a mica schist. This type of occurrence has been mentioned previously.

Kyanite and Sillimanite	26%
Mica	25
Feldspar	20
Quartz	18
Garnet	1
Accessory minerals Tourmaline, Hornblende, Magnetite	10

Table No. 2 Mineralogic composition of the crude.

The macroscopic examination of the ore showed it to contain many free blades of kyanite up to three-fourths inch long. Smaller crystals ranging down to nearly microscopic size were firmly imbedded and thoroughly disseminated through the schist fragments.

Preparation of the Mineral Crude. The mineralogical association indicated to the investigator the necessity of a selective method of separating the kyanite. For this reason flotation was considered most applicable, and the mineral crude was prepared for flotation studies. Therefore, the material was crushed and ground to all minus 35 mesh; and, from this material aliquot portions were obtained for all testing methods.

One variation of the above procedure for preparation of the sample was considered. The crude unground material was wet ground in the laboratory rod mill for twenty minutes to determine the possibility of differential grinding and screening.

Screen Analysis. A representative portion of the crude was wet ground for 20 minutes in the rod mill and a screen analysis was performed. The results were shown in table No. 3. The results of this screen analysis can be contrasted with that of the crude (material as received) table No. 4.

Openings		Tyler Mesh	Sample Weights	Per Cent	Per Cent Cumulative Weights
Inches	Millimeters				
0.263	6.680	3	21.0	4.1	4.1
.185	4.699	4	8.2	1.6	5.7
.131	3.327	6	4.8	0.9	6.6
.093	2.362	8	2.0	0.4	7.0
.065	1.651	10	1.2	0.2	7.2
.046	1.168	14	0.6	0.1	7.3
.0328	.833	20	0.4	0.1	7.4
.0232	.589	28	0.4	0.1	7.5
.0164	.417	35	3.8	0.7	8.2
.0116	.295	48	12.6	2.5	10.7
.0082	.208	65	23.6	4.7	15.4
.0058	.147	100	39.8	7.8	23.2
.0041	.104	150	389.4	76.8	100.0

Table No. 3 Screen analysis of material wet ground in rod mill for 20 minutes.

Openings		Tyler Mesh	Sample Weights	Per Cent	Per Cent Cumulative Weights
Inches	Milli-Meters				
0.525	13.33		71.0	13.0	13.0
.263	6.680	3	150.6	27.7	40.7
.185	4.699	4	62.8	11.5	52.2
.131	3.327	6	43.2	7.9	60.1
.093	2.362	8	38.6	7.1	67.2
.065	1.651	10	33.6	6.2	73.4
.046	1.168	14	32.2	5.9	79.3
.0328	.833	20	26.2	4.8	84.1
.0232	.589	28	20.4	3.8	87.9
.0164	.417	35	16.6	3.1	91.0
.0116	.295	48	13.4	2.5	93.5
.0082	.208	65	10.0	1.8	95.3
.0058	.147	100	8.0	1.5	96.8
.0041	.104	150	5.8	1.1	97.9
.0029	.074	200	4.0	0.8	98.7
.0029	.74	200	7.8	1.3	100.0
		Totals	544.2	100.0	100.0

Table No. 4. Screen analysis of crude material.

Liberation Studies. Sieve fractions of the screen analyses were examined under the binocular microscope to determine the mesh size at which complete liberation of the kyanite occurred. No locked particles were noted in the 10-mesh fractions. The 8-mesh material was noted to contain a few garnets enclosed within some of the kyanite crystals. There appeared to be no segregation of the kyanite into any sieve fraction; therefore, it is concluded that there is no differential grinding of the kyanite.

Table Concentration. A preliminary test of the possibilities of tabling, indicated that the ore could be graded up considerably by its use. Approximately 12,000 grams of minus 35-mesh material assaying about 27% kyanite-sillimanite was tabled on a laboratory Wilfley Table. A concentrate weighing about 8500 grams and assaying 31%, and a mica tailing of nearly 1000 grams containing only 5% kyanite-sillimantite were obtained. The slimes, collected and dried, weighed approximately 1300 grams and assayed 25% kyanite-sillimanite.

A macroscopic inspection of the mica tailing from the table indicated a relatively clean mica concentrate that might possibly have some marketing possibilities as scrap or ground mica. The table concentrate was used as the head sample for several flotation tests and also for the electrostatic separation.

Flotation Studies. It was decided to test several reagents of selective nature to determine their capabilities as collectors. The favorable quantity of reagent was determined by starvation tests at the natural pH (about 8.5) of the ore. Holding all other variables constant, tests were conducted varying the pH by conditioning with NaOH or HCL. Copies of the laboratory test sheets are included in the appendix.

Frother Tests. A frother having the very minimum of collecting powers was desired so as not to obscure the results of the collector reagent added. Consequently, a full series of tests were performed using only the frothers pine oil and terpineol. Alternatively it was thought possible that the frothers might collect and thereby float a large percentage of the mica and provide a method of eliminating that troublesome constituent at the outset of later flotation tests. Figure No. 1 illustrates the variation in weight of floated material pulled over a four minute period with pH, for each of the frothers tested.

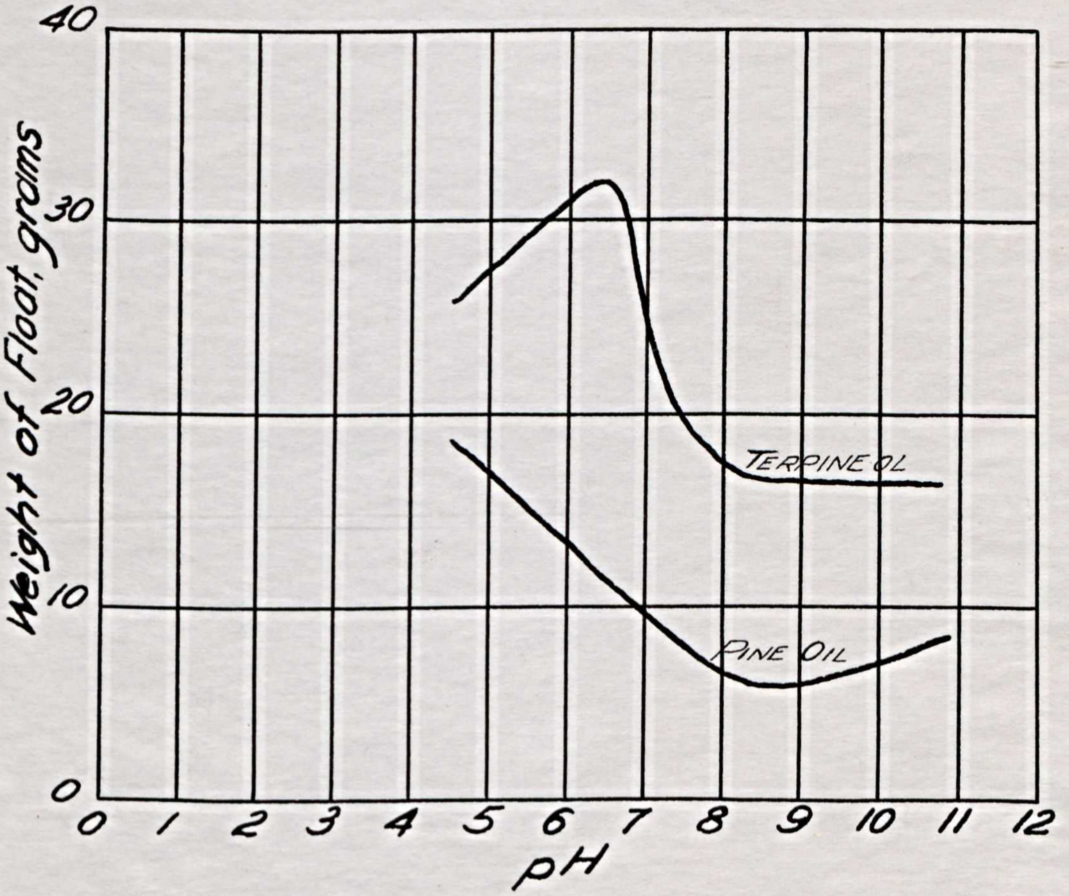

FIG. 1.-RELATIONSHIP OF PH TO RECOVERY WITH TERPINEOL AND PINE OIL.

Regardless of the greater collecting properties of the terpineol, it was selected for subsequent tests because the froth produced was more stable and slightly more persistent than the pine oil froth. Elastic, strong, large bubbles should prove to be of advantage to lift the heavy acicular kyanite crystals.

<u>Aerosol OT.</u> A starvation test performed by adding successive amounts of the reagent and weighing the floated product determined 0.2 lb per ton as being the desireable quantity for the subsequent tests. Terpineol was added as required to produce a suitable froth. The burdened froth was pulled for two minutes. Variation of recovery with pH is illustrated by Figure No. 2.

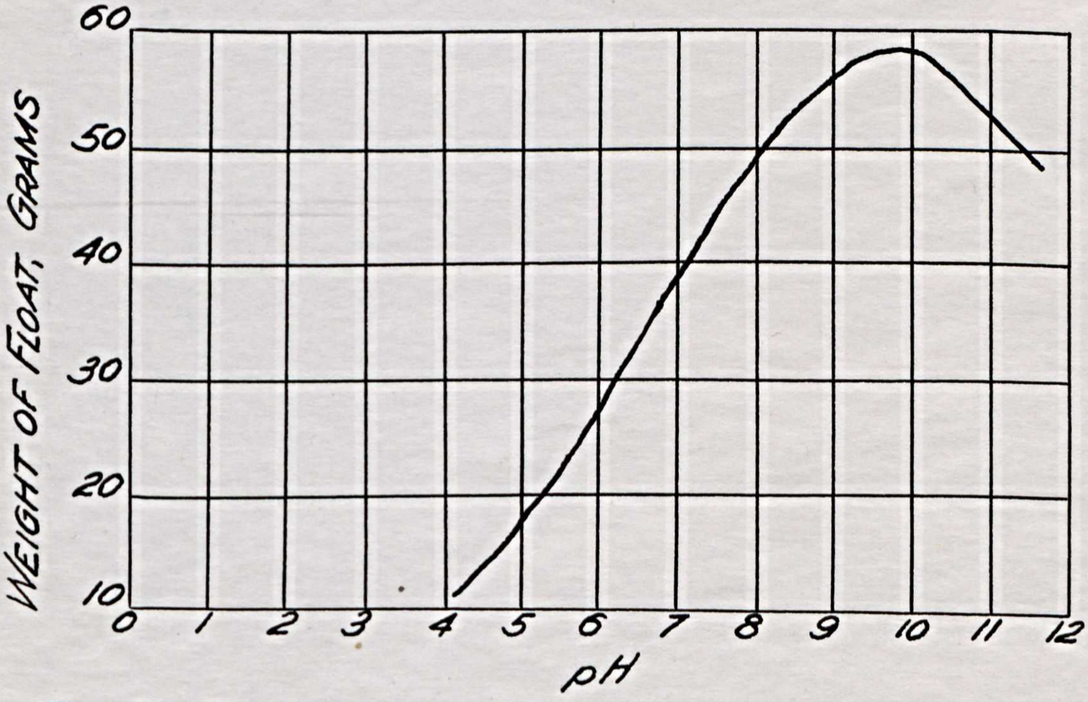

FIG. 2—RELATIONSHIP OF PH TO RECOVERY WITH AEROSOL OT

The floated material consisted mostly of mica and very fine slimes. The conclusion is that there is no selective kyanite recovery with this reagent, but some mica can be floated.

Tri-Methyl Cetyl Ammonium Bromide. This reagent with proven reputation as a quartz collector was tested with a view to possibly removing the quartz and leaving an enriched kyanite concentrate. A starvation test indicated 0.5 lb per ton of reagent as optimum. With a pulling time of 2 minutes, Figure No. 3 illustrates the variation of recovery with pH.

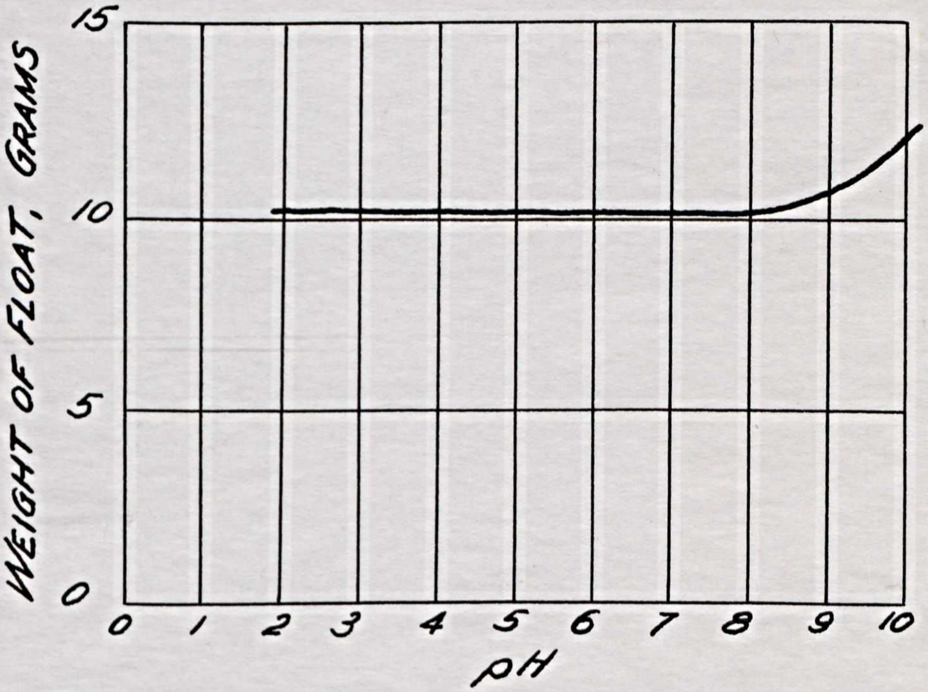

FIG. 3.-RELATIONSHIP OF PH TO RECOVERY WITH TRI-METHYL CETYL AMMONIUM BROMIDE

Resulting weights and mineralogic composition of products lead to the discouraging conclusion that this reagent is ineffective. The reader's attention, however, is directed to the near independence of recovery and pH. This may be attributed to the nonionizing character of the reagent.

Lauryl Amine Hydrochloride. The procedure heretofore followed was relaxed to the extent of permitting adjustment of pH during the original test. In no instance was there a significant amount of floated material. The lack of constancy in procedure does not permit of reporting any comparative figures.

Reagent 825. At this point in the investigation, information of some research on flotation of kyanite by use of the American Cyanimid Collector Reagent 825 was obtained. Understanding that a long conditioning time in an extremely acid and dense pulp contributed to the recovery, a starvation test was conducted using a pebble mill as conditioner. The results were very gratifying. 3 lbs per ton of the reagent proved to give optimum results. The reagent acts as its own frother. Addition of either terpineol or pine oil ruined the froth. In later tests the mica was floated first by use of Aerosol OT at its most favorable collecting conditions of pH about 8 and using 0.3 lb per ton of reagent. The Wilfley Table concentrate was the test sample used. A special impeller conditioner was fashioned to give a slow mixing of the pulp.

Five 600 gram charges were treated with the Aerosol OT. The total mica removed weighed 134.2 grams. The balance of the material was dewatered and re-pulped to 65% solids, 38.8 lbs per ton of H_2SO_4 were added and the material conditioned at a pH of 0.72. At ten minute time intervals a volume of the pulp approximating a 600 gram dry charge was removed from the conditioner and diluted to the customary 23% pulp density. A flotation test was performed on it, using 3 lbs per ton of reagent 825. pH of the diluted portions varied slightly from 1.62 to 1.75. In each of the four tests the limit of the froth was 2½ minutes. Terpineol would not revive the froth and even seemed to reduce it. Bubbles were large and heavily burdened with the gray-blue kyanite crystals.

Figure No. 4 indicates variation in the weight of concentrate with conditioning time. All other variables approximately constant.

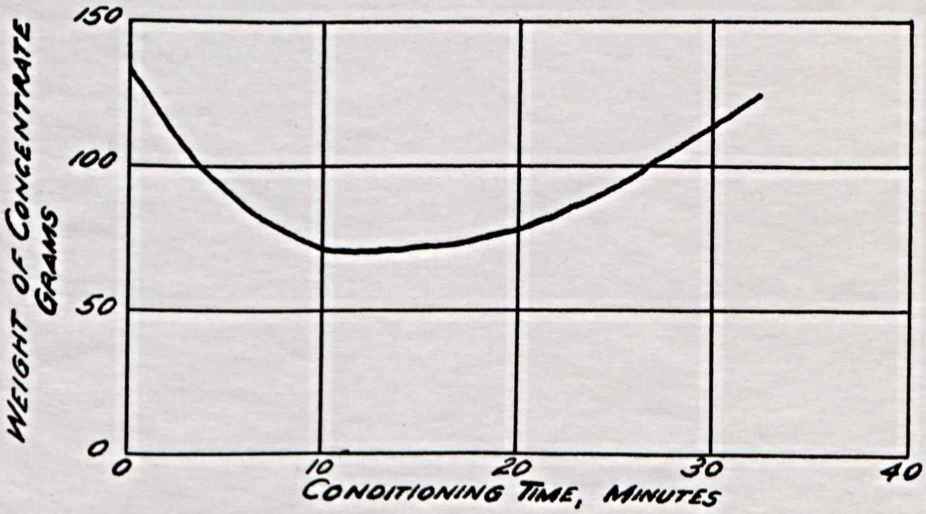

FIG. 4–RELATIONSHIP OF CONDITIONING TIME TO RECOVERY WITH REAGENT 825

The relatively high recovery at 0 conditioning time is explainable only on the basis of unequal froth pulling conditions. Some irregularity must have entered the manual process though it was attempted to maintain as even pulling conditions from test to test as possible.

Results tabulated in Table No. 5 show a recovery of 33 to 55% in concentrates of from 97 to 98%.

Treatment	Concentrate			Tailing	
	Weight Per Cent	Recovery Per Cent	Per Cent Kyanite	Weight Per Cent	Per Cent Kyanite
0 Minutes Conditioning Time; pH = 1.62	22	55	98+	78	19
10 Minutes Conditioning Time; pH = 1.72	12	33	98+	88	27
20 Minutes Conditioning Time; pH = 1.70	14	37	98+	86	26
30 Minutes Conditioning Time; pH = 1.75	19	51	97+	81	22

Table 5–Recovery Employing Reagent 825

The recovery would undoubtedly have been much better had additional collector been added and the pulling time extended to the limit of the additional froth.

Electro-Static Separation. A selected portion of the table concentrate was employed for this test. A thin mica split was made, the material being passed over the separator four times. An additional four passes netted two additional products-a middling and a kyanite concentrate. The tabulated results follow in Table No. 6.

PRODUCT	WEIGHT GRAMS	WEIGHT PER CENT	KYANITE PER CENT
CONCENTRATE	450	46	71
MIDDLING	335	35	27
TAILING	187	19	13
FEED	972	100	44

TABLE 6.-RESULTS OF ELECTRO-STATIC SEPARATION

Assaying. An investigation fully as lengthy as this one could be conducted to determine an accurate method of assaying kyanite and other aluminous mineral constituents of an aluminous rock. There is no element in kyanite which is common to kyanite alone; consequently, mineral counts or a physical separation and subsequent weighing of the kyanite must be relied upon. For sake of simplicity and rapidity a sink-float method of separation of the kyanite was used.

One gram of the material to be assayed was thoroughly stirred in a methylene iodide solution of specific gravity of 3.1 in a separatory funnel. After a short settling period the heavy material was drawn off through the stopcock opening of the flask into a filter funnel set in a filter flask. The material was washed thoroughly with benzene, dried and weighed. The float material was similarly drawn off, washed, dried and weighed.

The difficulty encountered is in obtaining a complete separation because of the effects of adsorbed air on some particles with resulting buoyancy and the formation of floating agglomerates including some kyanite. Very fine particles may float because of surface tension of the liquid. At best these are merely close approximations of the kyanite-sillimanite content. The only guaranteed analyses are of the kyanite flotation concentrates which are at least 97 to 98 per cent. In each case the small amount of float contained significant amounts of kyanite and sillimanite as determined under the microscope.

Acetylene Tetrabromide is not a suitable liquid for sink float analysis of this ore because a large amount of the biotite having a specific gravity as high as 3.0 sinks in that liquid.

A chemical analysis was performed to determine Al_2O_3 content of the kyanite-sillimanite concentrates.

RECOMMENDATIONS

The very preliminary nature of this investigation connotes further study. At least, the results of this investigation are such that a more detailed study for the beneficiation of Montana Kyanite appears to be worthy of consideration.

While the flotation process successfully separates the kyanite from associated minerals, the very acid circuit and the rather high reagent consumption are objectionable. This objection, in all probability, can be overcome. The conditions for optimum economic application of flotation were not determined, but experimental evidence does indicate that upon better understanding of the conditions required for flotation, the commercial application would eventually be satisfactorilly accomplished.

Table concentration was used in this study to upgrade the kyanite crude and the results of this up-grading produced a satisfactory flotation feed. Nevertheless the possibility of up-grading the coarse fractions of material by applications of one of the dense media processes, should be considered. In any event, the beneficiation of kyanite is likely to follow a process of up-grading by some means, followed by flotation to obtain a final kyanite concentrate.

Since the marketing of kyanite, as well as other similar industrial minerals is often critical, sufficient kyanite concentrate should be obtained to forward samples to various users. Such a procedure would allow the investigator to accurately determine the requirements necessary for the kyanite concentrate and at the same time establish a possible price.

CONCLUSIONS

The experimental evidence gained in this preliminary investigation suggests that:

1) Kyanite can be concentrated to a satisfactory commercial grade by a combination of gravity concentration methods and flotation.

2) American Cyanamid Reagent 825 is a selective collector for kyanite.

3) To obtain results using the collector number 825 the pulp must be conditioned in a very acid circuit.

4) Concentrates containing at least 98 per cent kyanite-sillimanite were obtained.

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APPENDIX

FROTHER TESTS

Object: To determine the collecting effects of the frothers Terpineol and Pine Oil, when used singly and with no collector.

Conditions: The following conditions were identical in each test.

Weight of Sample . . . . 600 gms.
Pulp density, distilled water . . . . . . 23 %.
Mesh . . . . -35.
Flotation machine . . . . .Fagergren.
Temperature of pulp . . . . 23° C.
Conditioning time with pH adjustor . . . . 5 min.
Froth pulling time . . . . 4 min.
All reagents added to cell

Test #1. Reagents: 6.9 lb/T HCl, pH . . . . . . 5.0.
0.186 lb/T Terpineol
Products: Conc. 27.2 gms.; Tails 568.6 gms.
Remarks: Abundant froth of very temporary nature. Conc. contained mostly mica and slimes.

Test #2. Reagents: 3.45 lb/T HCl, pH 6.3
0.074 lb/T Terpineol
Products: Conc. 32.8 gms.; Tails 564.4 gms.
Remarks: Concentrate contained mostly mica and slimes

Test #3. Reagents: 1.73 lb/T HCl, pH . . . 7.3
0.037 lb/T Terpineol
Products: Conc. 21.2 gms., Tails 577.2 gms.
Remarks; Sufficient froth of persistent nature.
Product contains same as test #1.

Test # 4. Reagents: 0.037 lb/T Terpineol. pH . 8.8
Products: Conc. 16.4 gms., Tails 581.0 gms.
Remarks: Same as test # 1.

Test #5. Reagents: 0.667 lb/T NaOH, PH. . . . 10.4
Products: Conc. 16.2 gms., Tails 580.6
Remarks: Same as test #1.

Test #6. Reagents: 6.9 lb/T HCl, pH 4.7
0.031 lb/T Pine Oil
Products: Conc., 18.0 gms., Tails 578.4 gms.
Remarks: Not a very stable froth.

Test #7. Reagents: 3.45 lb/T HCl,pH 7.0
0.031 lb/T Pine Oil
Products: Conc., 9.8 gms., Tails 588.0 gms.
Remarks: More abundant froth, though not persistent.

Test #8. Reagents: 1.73 lb/T HCl, pH 7.4
0.031 lb/T Pine Oil
Products: Conc., 7.8 gms., Tails 590.0
Remarks: Same as test #7.

Test #9. Reagents: 0.031 lb/T Pine Oil, pH . . . . 8.9.
Products: Conc., 5.6 gms., Tails 591.8 .
Remarks: Same as test #7.

Test #10. Reagents: 0.667 lb/T NaOH, pH . . . . .10.5.
0.031 lb/T Pine Oil
Products: Conc. 7.4 gms., Tails 590.0
Remarks: Same as test #7.

AEROSOL OT

Object: To determine the comparative collecting powers of Aerosol OT at various pH's.

Conditions: The following conditions were identical for each test.

Weight of Sample	600 gms.
Pulp density, distilled water . . .	23 %.
Mesh	-35.
Flotation Machine	Fagergren.
Temperature of pulp	23°C.
Conditioning time with pH adjustor .	5 min.
Froth pulling time	2 min.
All reagent additions to cell.	
Amount of Aerosol OT	.0.200 lb/T.

Test #1. Reagents: 6.9 lb/T HCl, pH. . . . 4.3.
0.019 lb/T Terpineol
Products: Conc. 10.6 gms., Tails, 586.0 gms.

Remarks: Initially self-frothing, terpineol added as needed, thin froth. Concentrate of mica and some slime.

Test #2. Reagents: 0.019 lb/T Terpineol, pH . . . 8.0
Products: Conc. 52.0 gms., Tails 542.4 gms.
Remarks: Concentrate mostly of mica, few slimes.

Test #3. Reagents: 0.834 lb/T NaOH, pH. 10.2
Products: Conc., 58.6 gms., Tails, 536.0 gms.
Remarks: Self-frothing at this pH, no terpineol required.

Test #4. Reagents: 8.33 lb/T NaOH, pH 11.2
0.019 lb/T Terpineol .
Products: Conc. 52.2 gms., Tails, 543.0 gms.
Remarks: Self-frothing at this pH, Terpineol added in spite ofthis and an excessive and very persistent froth resulted.

TRI*METHYL CETYL AMMONIUM BROMIDE

Object: To determine the comparative collecting powers of Tri-Methyl Cetyl Ammonium Bromide at various pH's.

Conditions: The following conditions were identical in each test.

Weight of sample	600 gms.
Pulp density, distilled water.	23 %.
Mesh	-35.
Flotation Machine	Fagergren.
Temperature of Pulp	23°C.

Conditioning time with pH adjustor . . 5 min.

Froth pulling time. . . . . 2 min.

All reagents added to cell

Amount of Tri-Methyl Cetyl Ammonium Bromide 0.51 lb/T.

Test #1. Reagents: 30.0 lb/T H_2SO_4, pH . . . 1.9
0.057 lb/T Terpineol

Products: Conc. 10.2 gms., Tails, 584.8 gms.

Remarks; Concentrate consisted mostly of fine quartz.

Test #2. Reagents: 0.019 lb/T Terpineol, pH . . 8.3

Products: Conc., 10.2 gms., Tails, 584.0 gms.

Remarks: Same as test #1.

Test #3. Reagents: 0.668 lb/T NaOH, pH . . . 10.3
0.019 lb/T Terpineol

Products: Conc., 12.8 gms., Tails, 582.0 gms.

Remarks: Same as test #1.

REAGENT 825

Object: To determine the effects of conditioning time on recovery with reagent 825.

Conditions: The following conditions were identical in each test.

Weight of sample . . . . about 600 gms.

Pulp density, in cell . . . . 23 %.

Pulp density, in conditioner . . . . . 65 %.

pH of pulp . . . . 0.72.

Mesh . . . . -35.

Flotation Machine . . . . .Fagergren.

Temperature of pulp . . . . 23°C.

Froth pulling time. . . . . .2½ min.

Amount of reagent 825 added to cell . .3 lb/T.

24 lb/T H_2SO_4 added to conditioner pulp

Density of conditioned pulp. . . . . 65%.

Test #1. Conditioning time . . . . 0 min.

0.037 lb/T Terpineol, pH. . . . . . . 1.62.

Products: Conc. 147.8 gms. Tails 523.4

Remarks: Terpineol would not revive froth, and even seemed to reduce it. Not used on later tests. Heavily burdened froth.

Test #2. Conditioning time . . . . .10 min.

pH . . . . 1.72.

Products: Conc. 84.4 gms., Tails 612.4 gms.

Test #3. Conditioning time . . . . .20 min.

pH . . . . 1.70.

Products: Conc. 96.4 gms., Tails 613.8 gms.

Test #4. Conditioning time . . . . .30 min.

pH . . . . 1.75.

Products: Conc. 116.4 gms., Tails 497.0 gms.