73-13

CONFIDENTIAL

PRELIMINARY BENEFICIATION AND EVALUATION OF JORDANIAN FELDSPAR ORE

By

J. Philip Neal

Ore Dressing Specialist

North Carolina State University
Minerals Research Laboratory
180 Coxe Avenue
Asheville, North Carolina 28801

CONFIDENTIAL

PRELIMINARY BENEFICIATION AND EVALUATION OF JORDANIAN FELDSPAR ORE

MRL September 1973 Progress Report
Sample No. 4126 - Book No. 265
by
J. Philip Neal

I N D E X

BACKGROUND

In the latter part of 1972, the Minerals Research Laboratory was approached by Mr. Paul Talbott of Swindell-Dressler Company regarding possible research and development work on beneficiation of a granite from the Kingdom of Jordan. This nation was desirous of developing a facility producing feldspar and quartz concentrates for ceramic and glass production for that general area, and to this end was receiving assistance from the U. S. Agency for International Development. Swindell-Dressler Company, engaged as consultant by the Kingdom of Jordan, had requested technical assistance from the MRL on the basis of the Laboratory's experience with feldspar beneficiation. The Laboratory accepted the project, with the understanding that it would likely involve a preliminary bench work phase followed by a pilot plant operation. This report relates only to the bench flotation work (with related grinding, scrubbing, etc.) which took place in May, 1973 under one project proposal (JPN No. 21).

Certain background information had been developed regarding the ore body and its amenability to beneficiation. Sent to the MRL were copies of a geological report from Jordan's Natural Resources Authority, plus one on beneficiation of this granitic feldspar ore from the laboratories of the same agency. These reports, in brief, were optimistic regarding the potential of the ore body as a feldspar source, and gave some data relating to expected yield and grade. The beneficiation report served as an interesting basis for comparison with beneficiation at the MRL.

OBJECTIVES

So far as the bench work phase by the MRL was concerned, the following project objectives were set forth:

1) Confirm the amenability of the ore to beneficiation involving froth flotation, employing one or more circuits.
2) Develop research information useful in determining the relative efficacy of iron mineral flotation vs. high intensity magnetic separation to upgrade feldspar and quartz concentrates with respect to Fe_2O_3 level.
3) Establish, as closely as possible, the optimums on other variables connected with beneficiation of the ore, using flotation and related operations.
4) Report on findings and make recommendations regarding pilot plant preparation and operation.

SAMPLE DESCRIPTION

The sample was sent by Mr. Talbott in two consignments: an early one weighing about ten lbs. (received late in March, 1973), and a later one weighing 200 lbs. or more which arrived at the MRL on April 19, 1973. The consignments appeared to be essentially identical and were combined after a single bench test sequence had been run on the first (small) consignment. Aliquots were then split out of the total sample for subsequent tests.

In the Jordanian geological report previously cited, a series of gathered and evaluated samples was described and discussed (Samples No. G11 - G68). The Jordanian laboratory beneficiation report dealt with work on three area samples, each composited from about sixteen individual collections (Samples No. I, II, and III from Sample Groups F, B, and M). It was not possible to correlate the identity of MRL Sample No. 4126 with any specific sample or sample group cited in either of the above reports, except to observe that it had similar general characteristics to the reported samples beneficiated over there. Sample No. 4126, as received, was obviously from a hard, fresh, pink granite containing mainly feldspar, quartz, and biotite. The pink color of the feldspar was considered to be due to a low level of finely-dispersed hematite.

Prior to receipt by the MRL, the entire sample had been dry-crushed to about 95% minus 20 mesh. The opinion is expressed that certain information here developed on feldspar recovery could have been more accurate had there not been such a high initial level of minus 325 mesh in the head sample (over 13%). It is hoped that the head sample for pilot plant operation will not be crushed to this degree. It appears that, although this granite is unweathered, it is nevertheless quite prone to overgrinding.

Table I gives a screen analysis of the total sample, plus chemical assay of each screen fraction.

TABLE I

SCREEN & CHEMICAL ANALYSES OF SAMPLE NO. 4126, AS RECEIVED

U.S. Screen Size	% Wt	Chemical Assay % K_2O	% Na_2O	% CaO	% Fe_2O_3	Calc. % Feldspar in Frac.
+20	5.4 }	3.8	3.4	0.38	0.49	53.2
-20+30	14.2 }					
-30+50	26.8	3.9	3.9	0.41	0.40	58.2
-50+100	22.1	3.9	3.9	0.41	0.90	58.2
-100+200	11.4	4.2	4.0	0.38	0.90	60.7
-200+325	6.8	4.3	4.1	0.38	0.77	62.0
-325	13.3	4.6	4.4	0.52	0.77	67.1
Calculated Totals	100.0	4.0	3.9	0.41	0.66	58.6*

*Total percent of feldspar theoretically present in (100%) head feed.

Discussion of Data, Table I

The calculation of percent feldspar in each screen fraction is made on the basis of theoretical chemical assays of pure microcline (potash spar), albite (soda spar), and anorthite (calcium spar). The foumula is as follows:

$$\frac{\%K_2O}{16.9} + \frac{\%Na_2O}{11.8} + \frac{\%CaO}{20.1} = \text{percent feldspar in sample.}$$

Pure microcline should assay 16.9% K_2O, pure albite 11.8% Na_2O_3, and pure anorthite 20.1% CaO. Each, of course, would contain only one alkali metal, and so a theoretical total percentage of feldspar can be established. The presence of other minerals containing K, Na, and Ca will make this calculation inaccurate. However, in the case of this sample, there is judged to be an insufficient quantity of such other minerals to render this type evaluation invalid as at least a good proximate indicator of feldspar content, which is to say 58.6% of head feed. Specifically, the following feldspars would appear to be present, using the calculation cited:

K-spar (microcline)	- 23.6%
Na-spar (albite)	- 33.0%
Ca-spar (anorthite)	- 2.0%
Total	58.6%

Looking at the last column of Table I, it can be seen that the minus 325 mesh fraction contains a definitely higher percentage of feldspar than the average. The 200-325 fraction is also higher than average in feldspar content. These two fine fractions together, in fact, contain, by calculation, slightly over 22% of the total feldspar in the sample. In the preparation of this type ore for flotation, it is desirable to keep the minus 200 fraction to a minimum. It is usually possible to deslime efficiently at 200 to 325 mesh, but this would still cause considerable loss of values if this ore were commercially ground as the sample on hand.

BENEFICIATION TESTS

Preliminary Float Test

Upon receipt of the first consignment of the sample, it was beneficiated by a procedure which had been used in an earlier evaluation of a large variety of North Carolina feldspathic samples. This procedure involved these steps, in the order stated:

1) Grinding to minus 30 mesh.
2) Attrition scrubbing at thick solids plus desliming at 325 mesh.
3) Conditioning and flotation for micaceous minerals.
4) Conditioning and flotation for iron-bearing minerals.
5) Passage through a wet, high intensity magnetic separator.
6) Feldspar rougher and cleaner flotation.

This preliminary testing was intended to indicate whether usual wet beneficiation techniques would work, and to show what grade might be expected in feldspar and quartz concentrates. Yield and recovery were not expected to be the best attainable.

Table II gives some essential data on this preliminary test.

Discussion of Data, Table II

This test showed that the sample was a good ore of feldspar and quartz. Although there were some unnecessary losses, indications were that a concentrate yield of 50% or better appeared possible for feldspar, and 26% or higher for quartz.

TABLE II

PRELIMINARY WET BENEFICIATION ON SAMPLE NO. 4126

Lab. No. 4126 - Test No. 1 - Date 27 March 1973

Product	% Wt	Assay, Non-Mag. Spar & Qtz. %Al_2O_3	%K_2O	%Na_2O	%CaO	%Fe_2O_3
Mica Froth Prod.	0.9					
Iron Mnrl. F.P.	6.4					
Mag. Prod., Spar/Qtz.	0.8					
Spar Conc., Non-Mag.	49.2	18.45	6.44	6.02	0.59	0.12
Qtz. Prod., Non-Mag.	26.3	0.30	0.12	0.07	-	0.03
Slimes & Losses	16.4					
Total	100.0					

Process	(Min) Time	% Solids	pH	Reagents (lbs per ton,head feed, 1000 grams) NaOH	TE-42	RADA	HF	M-70	Ar-T	H-25	PO	FO
Scrub	10	75		2.0								
Deslime on 325 M.	(3 x 20 sec.)											
Mica Float Cond.	1	45	9.0	0.2	0.1	0.2						
Mica Float										0.05		
Iron Min. Fl. Cond.	7	70	3.2				0.75	1.0			0.10	
Iron Mineral Float												
Wet Mag.Sep.,2 passes	1/2	15										
Spar Float Cond.	3	55	3.2				0.75		0.25			0.75
Spar Rougher Float										0.05		
Spar Cleaner Float												

Remarks:

Prior dry grind: Single stage, on +30 fraction only, 1.5 min. in small steel mill, 10 rods.

HIW mag. separator operated at max. intensity. Double throughput.

All flotations carried out in Denver lab cell, 1000 g. size.

Description of Reagents:

(Igepon) TE-42: Anionic taurate, General Aniline & Film Corp.
RADA : Rosin amine acetate, Hercules Inc.
M-70 : Petroleum sulfonate, Mineral Oil Refining Co.
H-25 : Glycol frother, Hunt Chemicals
Armac T : Tallow amine acetate, Armour Chemical Co.
PO : Pine oil, Hercules Inc.
FO : No. 2 fuel oil

Using calculations of the sort previously cited, it was established that the final feldspar concentrate contained close to 8% free silica, despite two cleaner floats: a matter for further investigation. Recovery of feldspar was about 78% of total, with the bulk of the loss in the slimes (minus 325 mesh), and a slight amount in the first two froth products.

The flotation of feldspar in the third float circuit appeared rather usual in all respects. This gave no warning of a peculiar phenomenon which occurred in later feldspar flotations carried out under different conditions. That was the apparent necessity to use an exceptionally high level of amine collector to fully float the feldspar when feldspar was the only mineral floated.

Following this relatively successful test, it remained to be seen what beneficiation steps could be omitted. It appeared that a mica float was unnecessary since biotite, the principal contaminant of this sample, could be removed by either a petroleum sulfonate float for iron minerals or by magnetic separation.

Tests for Iron Mineral Removal

Bypassing, for the moment, the potential major loss of feldspar from overgrinding, it was considered essential to learn the comparative effects on grade and recovery of high-intensity wet magnetic separation vs. the usual type of iron-mineral flotation using an acid circuit and petroleum sulfonate collector. A group of three tests checked out these techniques. Tests in this group embodied three different procedures. Table III describes further, and gives data on, these three tests.

TABLE III

THREE TESTS RELATED TO IRON-MINERAL REMOVAL

Test No.	Description of Test
2	1000-gram aliquot of head sample screened dry on 20 mesh. Plus 20 only ground to minus 20 by 1-minute run in small rod-mill. Total sample then washed thru Eriez HIW batch magnetic separator twice, at maximum intensity, using 1/4 in. grids & very slow throughput. Total magnetics and non-magnetics dried.
3	1000-gram aliquot size-reduced as Test 2. Agitated at 60% solids for 2 minutes, diluted and deslimed twice on 325 mesh. Conditioned for 7 minutes at 65% solids with 1.5 lbs/T M-70 petroleum sulfonate, 2.0 lbs/T of H_2SO_4 (pH = 2.4), and 0.1 lb/T pine oil. Flotation carried out in Denver batch float cell, 1000 gram size.
4	Preparation as Test 3, but attrition scrub substituted for agitation. Scrubbed for 10 minutes at 75% solids with 2.0 lbs/T of NaOH, then diluted and deslimed twice on 325 mesh. Iron mineral flotation as Test 3.

Products	% Wt. Test No. 2	% Wt. Test No. 3	% Wt. Test No. 4
Spar/Qtz. Non-Mag.	95.3	-	-
Magnetics	2.5	-	-
Iron-Mineral F.P.	-	3.3	3.0
Spar/Qtz. M.D.	-	83.8	82.2
Slimes	- }	12.9 }	14.8
Loss	2.2 }		
Total	100.0	100.0	100.0

SCREEN ANALYSES & Fe_2O_3 ASSAYS

	Test No. 2 Spar/Qtz. Non-Magnet.		Test No. 3 Spar/Qtz. M.D.		Test No. 4 Spar/Qtz. M.D.	
U.S. Screen	% Wt.	%Fe_2O_3	% Wt.	%Fe_2O_3	% Wt.	%Fe_2O_3
+30	12.9	0.13	12.5	0.34	12.2	0.20
-30+50	32.5	0.11	35.1	0.18	35.5	0.12
-50+100	26.7	0.10	28.3	0.091	28.9	0.08
-100+200	14.1	0.097	14.4	0.080	14.6	0.08
-200+325	6.9	0.097	6.8	0.074	6.6	0.074
-325	6.9	0.19	2.9	0.089	2.2	0.091
Total	100.0	0.11 (calc.)	100.0	0.15 (calc.)	100.0	0.11 (calc.)

Discussion of Data, Table III

It can be seen that the plus 50 mesh fraction is beneficiated better by HIW magnetic separation, but that flotation apparently works better on the finer fractions, so far as quality is concerned. The HIW magnetic separator might very well work better on fines if certain adjustments were made. Generally speaking, this machine appears more useful on plus 200 mesh material. Iron mineral flotation (acid + petroleum sulfonate) sometimes comes close to its limits of performance in the 20-30 mesh size range. Particles of this size often float poorly.

When the percentages of fines (slimes) are disregarded, the percent yield of spar-quartz product varies little among the three tests. Since, in the final flowsheet, a minimum level of slimes should be projected, these three tests might be considered close to equal in yield. Test No. 3, however, falls qualitatively short of Test No. 4; and the difference between these two is the use of attrition scrubbing in No. 4, and no scrubbing in No. 3. Attrition scrubbing apparently created very few additional slimes (14.8% vs. 12.9%), but effected considerable difference in product quality 0.15% Fe_2O_3 vs. 0.11% Fe_2O_3).

The Fe_2O_3 assays on the respective screen fractions of the non-magnetic products of Tests 2, 3, and 4 indicate that grinding the sample to minus 30 mesh is probably desirable. Actually, a grind to minus 50 mesh appears best, but is probably sub-marginal in terms of increased cost. Again, the grinding of this ore appears a crucial matter. Technique must be carefully worked out to bring size range within desired limits without creating excessive minus 200 mesh fines.

Miscellaneous Tests

Test No. 5 was an attempt to float feldspar immediately, and also to replace attrition scrubbing with low-intensity agitation. The resulting feldspar float was defective. Much feldspar remained with the quartz machine discharge. This indicated that either some degree of attrition scrubbing was needed, or that amine collector level would have to be increased if scrubbing were eliminated. Since iron-mineral flotation was also more of a problem without attrition scrubbing (Test No. 3), the evidence in favor of scrubbing seemed to increase.

Several abortive float tests gave the first indication of an unexpected phenomenon. These tests were not included in the numbered series. All of these tests involved attempts to perform a standard fledspar-from-quartz separation as a one-and-only float, ignoring for the moment the need to remove iron minerals. First, feldspar flotation was tried immediately following an agitation-plus-deslime step. A second one was tried after subjecting a ten-to-fifty mesh portion of the sample, weighing 1000 grams, to wet rod milling until it was all minus 30 mesh, then desliming and conditioning. Following that was tried attrition-scrubbing a size-reduced 1000-gram aliquot, then desliming and conditioning it. For all three tests, 0.25 lb/T of amine collector was used in conditioning, as Test No. 1. In the first two tests there was virtually no feldspar floated, and this tended to eliminate the theory that the need, in this situation, was for particle surfaces which had been freshly wet-ground. In the case of the third test (attrition scrub), there was still incomplete feldspar flotation, although there was some improvement over the first two tests. The difference between this last test and Test No. 1 was the lack of preceding conditioning (reagentizing) and flotation. Therefore, the preceding of the feldspar float by one or more prior reagentizing and float steps appeared to be a significant factor. This was somewhat borne out by an additional float test with attrition scrubbing, desliming, and iron mineral flotation preceding feldspar conditioning and flotation. In this case, about 85% of the feldspar floated. Possibly, the reagentizing of previous float steps has the effect of sealing small pores or cracks in the feldspar which otherwise absorb the amine collector, which absorbtion probably causes incomplete reagentizing of particle surfaces. This can only be a tentative theory at this point. A final test in this series was then begun in the manner of Test No.1: with attrition scrub, but without mica and iron-mineral floats. In the conditioning step for feldspar flotation, 1.25 lb/T of amine acetate and 1.5 lbs/T of fuel oil were used: a very great increase from 0.25 lb/T of amine acetate and 0.75 lb/T of fuel oil. This increase in reagents resulted in a substantially complete feldspar flotation.

It should be borne in mind that determination of proper technique for floating feldspar as a one-and-only flotation step is of some importance in this situation because of the possibility of doing that in a final plant flowsheet: i.e. the only preceding step on the float feed might be HIW magnetic separation, with no prior mica or iron-mineral flotation.

Tests on Amine Level

Since tallow amine acetate is a relatively expensive reagent, a test series was run to determine whether less than 1.25 lbs/T might be adequate to do a complete separation of feldspar from quartz. The series involved a single variable: the amount of tallow amine acetate added to the conditioner. Each 1000-gram sample aliquot was dry-screened on 20 mesh, and the plus 20 was dry-ground long enough to pass about 95% through 20 mesh. The recombined sample was then attrition-scrubbed, deslimed, and subjected to conditioning and flotation to separate the feldspar froth product. Two cleaners were run on the feldspar. Table IV gives procedure on the test series, and Table V gives quantitative and qualitative data for evaluation. This series was run to determine necessary collector level when one float only (for feldspar) was run.

TABLE IV

FIVE TESTS ON AMINE LEVEL, SINGLE FLOAT, CONSTANT CONDITIONS
(TESTS NO. 14, 15, 16, 17 and 18)

Conditions				Reagents (lbs per ton, H.F., 1000 g.)				
Process	(Min.) Time	% Solids	pH	NaOH	HF	Al.26	H-25	F.O.
1. Dry grind + 20 to -20	1.0	100	-					
2. Attrition Scrub	10	75	9	2				
3. Deslime on 325 Mesh,	2 x 30 sec							
4. Spar Float Cond. (in cell)	2	40	3.0		1.5	(See Table 5)	0.05	1.5
5. Spar Rougher Float								
6. Spar Cleaner Float #1								
7. Spar Cleaner Float #2								

Reagents

Alamac 26 - Tallow amine acetate, General Mills. Varied between 0.25 and 1.25 lbs/T. Other reagents as Table II

TABLE V

QUANTITATIVE RESULTS, 5 - TEST SERIES, VARIABLE AMINE LEVEL
(TESTS NO. 14, 15, 16, 17 & 18)

Spar Concentrate	Test No. 14 0.25 lbs/T Amine	Test No. 15 0.50 lbs/T Amine	Test No. 16 0.75 lbs/T Amine	Test No. 17 1.0 lbs/T Amine	Test No. 18 1.25 lbs/T Amine
% Weight	41.1	49.6	52.2	54.4	55.5
% K_2O Assay	5.98	6.26	6.34	6.12	6.44
% Na_2O Assay	6.02	5.78	5.96	5.86	6.04
Middlings					
% Weight	4.3	3.2	3.4	3.6	3.7
% K_2O Assay	3.70	2.38	2.18	1.74	1.32
% Na_2O Assay	3.38	1.90	1.76	1.42	1.12
Quartz M.D.					
% Weight	40.6	33.0	29.9	27.1	26.5
% K_2O Assay	2.00	1.21	0.75	0.43	0.39
% Na_2O Assay	1.46	0.80	0.53	0.31	0.27
Slimes & Loss (No Assay)	14.0	14.2	14.5	14.9	14.3
Total	100.0	100.0	100.0	100.0	100.0
Calculated % Feldspar Distr.*					
In Spar Conc.	74.7	88.4	92.7	95.5	96.5
In Middlings	4.7	2.1	1.8	1.6	1.2
In Qtz. M.D.	20.6	9.5	5.5	2.9	2.3
Total	100.0	100.0	100.0	100.0	100.0

*These figures are based only on the K and Na-spar in the spar conc., middlings, and quartz M.D. No accounting is made for Ca-spar, or for feldspar losses in the slimes. Thus, the absolute figures are valid only for comparison from test to test in the series.

Discussion of Data, Tables IV & V

In this series, the sample was ground down only to minus 20 mesh rather than minus 30, in order to have a means of observing more clearly the limitations and marginal aspects of the tests of this series. The feldspar above 30 mesh size was markedly harder to float than that below 30 mesh, and its gradual diminution in the quartz M.D., as collector was increased,was easy to observe. Also, it caused considerable variations in assays from test to test,especially in the quartz product. It was thought at first that, if the 20 to 30 mesh fraction approached impossibility of flotation, each test could be re-evaluated in terms of its minus 30 mesh fractions only. That was done in the case of one of the tests (No. 17), reported immediately following.

Additional Testing of Amine Level

With one of the previous tests (No. 17) which came short of giving the best results in the series, the quartz machine discharge product was screened on 30 mesh, and the two fractions assayed. Table VI shows data.

TABLE VI

EVALUATION OF PLUS 30 AND MINUS 30 MESH FRACTIONS
OF QUARTZ PRODUCT, TEST NO. 17

Screen Fraction	% Weight	Chem. Assay % K_2O	Chem. Assay % Na_2O
Plus 30	17.8	1.78	1.12
Minus 30	82.2	0.19	0.12
Total	100.0	0.47 (calc.)	0.30 (Actual: 0.43 & 0.31)

Discussion of Data, Table VI

Alkali assay of the minus 30 mesh quartz indicates that, had the sample for this test been ground to that size, there would have been markedly better feldspar recovery in the spar concentrate, and the quality of the quartz would have been considerably improved. Further tests, involving grinding to minus 30 mesh and then trying a quantity of amine collector as low as 0.50 lb/ton, seemed indicated.

Tests Aimed At Optimum Conditions

Prior to the amine level series, but when it was already known that a high amine level might be needed, two tests were run under conditions believed close to optimum to compare iron mineral flotation and HIW magnetic separation. In both tests, the sample was first screened to remove all minus 325 mesh material. The plus 30 mesh fraction was then rod-milled in three stages to avoid overgrind, and recombined with the remainder. The resulting feed was then attrition-scrubbed and processed as described below. Another objective of these two tests was to give a demonstration of possible actual recovery of feldspar in the absence of overgrind, disregarding, in these tests, the losses from discarding the fines already existing in the sample as received.

Table VII gives essential data on processing and test results.

TABLE VII

TWO TESTS COMPARING IRON FLOAT vs. HIW MAGNETIC SEPARATION

Test No.	Description of Tests
8	Sample aliquot screened dry, minus 325 material removed until 1000 grams of +325 obtained. Plus 30 fraction of this rod-milled dry in 3 stages, each followed by screening: 1 minute, 1/2 minute and 1/2 minute. Recombined sample (without original minus 325) attrition-scrubbed as in previous tests, deslimed, and processed with iron-mineral and feldspar flotation, plus two cleaner floats.*
13	Preparation as Test No. 8, but scrubbed deslimed feed put through HIW magnetic separator, then processed with feldspar flotation and cleaners.*

*Amine level in feldspar rougher float was 1.0 lbs./T calculated against 1000 g. of feed to scrubber.

PRODUCTS & ASSAYS

	Test No. 8					Test No. 13				
		Chemical Assay					Chemical Assay			
Products	% Wt.	% K_2O	% Na_2O	% CaO	% Fe_2O_3	% Wt.	% K_2O	% Na_2O	% CaO	% Fe_2O_3
Iron-Min. F.P.	2.4	3.5	2.8	1.11	-	-	-	-	-	-
Magnetics	-	-	-	-	-	1.8	-	-	-	-
Spar Conc.	56.2	6.5	6.0	0.51	0.13	59.3	6.6	6.2	0.50	0.16
Middlings	5.4	2.5	2.0	0.23	0.10	2.7	0.6	0.4	0.09	0.05
Quartz M.D.	28.2	0.13	0.09	0.02	0.04	29.6	0.18	0.11	0.05	0.03
Slimes	6.1	4.7	4.3	0.41	1.53	5.5	5.5	4.4	0.36	1.59
Loss	1.7	-	-	-	-	1.1	-	-	-	-
Total	100.0					100.0				

(TABLE VII continued)

(TABLE VII continued)

ASSAYS OF SCREEN FRACTIONS OF SPAR AND QUARTZ

Test No. 8

Screen Fraction	Spar Concentrate % of Prod.	% K_2O	% Na_2O	% CaO	% Fe_2O_3	Quartz M.D. % of Prod.	% K_2O	% Na_2O	% CaO	% Fe_2O_3
+50	38.1	6.5	5.9	0.51	0.14	41.1	0.21	0.12	0.13	0.04
-50+100	35.3	6.4	6.1	0.53	0.13	36.9	0.07	0.04	0.01	0.02
-100+200	17.3	6.8	5.9	0.49	0.12	16.2	0.04	0.03	0.01	0.02
-200	9.3	6.7	5.9	0.46	0.12	5.8	0.06	0.03	-	0.02

Test No. 13

Screen Fraction	Spar Concentrate % of Prod.	% K_2O	% Na_2O	% CaO	% Fe_2O_3	Quartz M.D. % of Prod.	% K_2O	% Na_2O	% CaO	% Fe_2O_3
+50	39.1	6.1	5.7	0.51	0.14	42.5	0.33	0.19	0.08	0.04
-50+100	33.9	6.7	6.2	0.60	0.13	34.9	0.07	0.04	0.05	0.02
-100+200	16.8	6.8	6.2	0.56	0.11	15.7	0.04	0.03	0.04	0.02
-200	10.2	6.9	5.9	0.52	0.12	6.9	0.04	0.04	0.03	0.02

Certain additional data can be derived. Table VIII indicates the distribution of feldspar throughout the products of the two tests, based on chemical assays shown in Table VII.

TABLE VIII

FELDSPAR DISTRIBUTION IN PRODUCTS, TESTS NO. 8 AND 13

	Test No. 8			Test No. 13		
Product	% Wt. of Prepared Sample	% Spar In Prod.	Spar, % of Prep.Sample	% Wt. of Prep.Sample	% Spar In Prod.	Spar, % of Prep.Sample
Iron-Min.F.P.	2.4	49.9	1.2	-	-	-
Magnetics	-	-	-	1.8	(est.) 40.0	0.7
Spar Conc.	56.2	91.6	51.5	59.3	91.9	54.5
Middlings	5.4	32.8	1.8	2.7	6.8	0.2
Quartz M.D.	28.2	1.7	0.5	29.6	2.3	0.7
Slimes	6.1	66.2	4.0	5.5	71.7	3.9
Losses	1.7	(est.) 58.0	1.0	1.1	(est.) 58.0	1.0
Total	100.0	-	60.0*			61.0*

*These figures come out slightly higher than calculated feldspar in head feed.

Discussion of Data, Table VII - VIII

Principal difference between the two tests is seen in the percent yield of feldspar. However, this is partly due to a difference in the middlings from the cleaner floats. That difference occurred due to some unexplained variable. In a plant flowsheet, the middlings would be returned in closed circuit, and the feldspar therein presumably would be substantially recovered. On this basis, feldspar recovery in Test No. 8 would be 88.8% of the initial screened sample; and in Test No. 13 the figure would be 89.6%. This cannot be regarded, at this point, as a significant difference. Looking at a projected plant flowsheet, a recovery figure of 88 to 90% appears a valid target. Calculating against deslimed flotation feed, as is sometimes done, would produce a still higher figure.

Comparison of iron-mineral removal by flotation vs. magnetic separation shows some tendency of the latter to remove less feldspar, thus effecting slightly higher recovery. Visual inspection of this product from Test No. 13, compared to the iron mineral froth product from Test No. 8, suggests a level of about 40% feldspar. Assay of the iron-mineral froth product from Test No. 8 indicated 49.9% feldspar. The difference, however, is considered small, and decision as to which process to use might well be based on other factors. In favor of magnetic separation would be these points:

1) Slightly higher feldspar recovery
2) Lower volume of reagentized effluent water
3) Straightforward, trouble free operation: less likelihood of variables lowering yield and grade.

An adverse factor regarding magnetic separation might be difficulty of obtaining parts or technical assistance in event of malfunction or breakdown.

In favor of iron mineral flotation, these considerations appear:

1) Lower initial cost of equipment
2) Ease of repair, maintenance, and even rebuilding at the plant site.
3) Possible easier discernment of malfunction by personnel with lesser technical training.

Adverse considerations include the greater likelihood that the float circuit system for iron minerals can easily drift away from optimum separation, due to variations in feed or lapses in personal efficiency or vigilance. The availability of reagents must also be considered.

A final, but important, consideration occurs. If a small amount of zircon is present in the final ore, the balance of favor might tip strongly toward flotation, which would tend to remove it. Fluorescent-light examination of the iron mineral froth product from Test No. 8 failed to show any zircon.

The quartz machine discharge appears to be of good quality for most grades of glass, so far as initial assay is concerned. More detailed chemical and mineralogical analysis is called for, however. Despite careful preparation of the test samples, both quartz and feldspar products probably contain too much minus 200 mesh material for glass applications. There should be some consideration of size classification as a possible means of removing fines in the final flowsheet.

The feldspar concentrate appears quite suitable, by usual criteria, for both glass and ceramic applications, again looking at preliminary assay. But like the quartz, it has a fine fraction which ordinarily would need removal prior to use in glass. This fine fraction, however, is probably quite suitable for ceramic use, and represents a cost reduction in terms of being already fine-ground. Finding use for the fine (minus 200) quartz may prove more difficult. It would be an excellent ingredient for sand-lime brick, but for this a very large quantity of sand is needed.

Although the feldspar concentrate does show acceptable characteristics as a raw material for glass and ceramics, there is present in it a certain level of free silica. All tests indicated a free silica level in the neighborhood of 8%, and this despite a standard procedure of running two cleaner floats on the feldspar froth product. Regarding this, a theory is offered which can only be proven when a substantial piece of rock (2 inches or larger) can be cut and a thin-section made for microscopic examination. It is suggested that this particular granitic sample may contain, within or around its macrocrystals of feldspar, a certain quantity of micro-grains of quartz, 40 microns or smaller in size. Such a characteristic would also account for the apparent friability of the sample: fracturing tends to occur more easily along crystal boundaries. There are actual occurrences of this phenomenon in certain granitic rocks, so this theory has a basis in fact. A relatively small weight percentage of quartz micro-grains would probably be sufficient to produce the characteristic.

The slimes, produced as they were, contain about 70% feldspar and, assuming a similar plant flowsheet, could conceivably be used as a flux in some end-product such as ground tile. Chemically, they are suitable for amber glass, but up to the present there is no known effort under way to agglomerate such a fine product into coarse particles for glass applications.

SUMMARY AND CONCLUSIONS

A hard granitic rock from Jordan was successfully beneficiated by grinding, attrition-scrubbing, desliming, HIW magnetic separation, and froth flotation into two saleable concentrates: feldspar and quartz. The feldspar appeared chemically suitable for glass or ceramics, and the quartz for most glass applications. Both products, however, contained too many fines, reflecting an extremely friable characteristic of the rock, even though it was apparently fresh and unweathered.

Possible recovery of the mineral feldspar from the head sample is projected at about 90%. Probable assay of the concentrate in a plant flowsheet would be on the order of 6.5% K_2O, 6.0% Na_2O, 0.6% CaO, and 0.14% Fe_2O_3, with yield against head feed between 57% and 60%. Attainable quartz yield (of a grade suitable for most glass) was judged to be 27 to 29%. Combined slimes and iron minerals would comprise the remainder.

Friability of the sample, plus apparent impossibility of removal of 8% free silica from the feldspar concentrate, suggests a mineralogy involving micro-grains of quartz interspersed in the relatively larger spar crystals - a hypothesis needing confirmation via thin-section examination.

Comparison of froth flotation with HIW magnetic separation to remove iron minerals resulted in data slightly in favor of magnetic separation so far as yield and recovery were concerned - with grade essentially equal. However, the edge of superiority was slight and possibly not the most significant consideration.

Efficient feldspar flotation appears unlikely unless the sample is first subjected to attrition scrubbing and desliming. The exact conditions of these steps need further investigation. Another factor calling for further testing is the high level of amine collector apparently required to float the feldspar completely from the quartz.

Comminution of the sample to minus 30 mesh (rather than minus 20) results in easier attainment of top grade and recovery.

RECOMMENDATIONS

Final Bench Tests

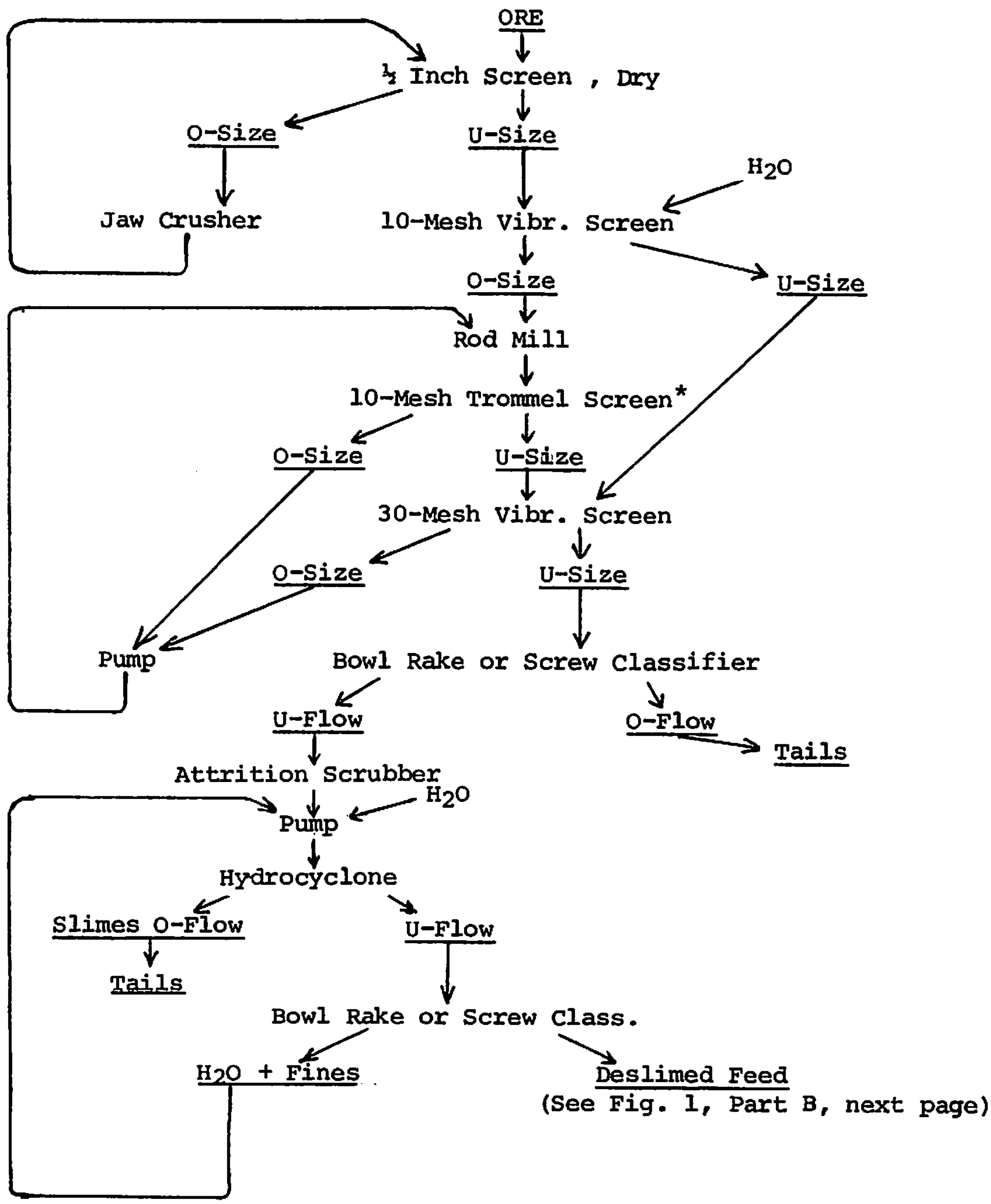
Past experience at the MRL points to the desirability of running final bench tests on the actual sample to be run in a pilot plant. Tests to date on Sample No. 4126 have indicated the likely steps called for. When a sample for pilot plant testing is received, confirmatory bench tests should be run, and final conditions more closely established.

Possible Pilot Plant Flowsheet

At this writing, the recommended pilot plant flowsheet has the format illustrated in Figure 1.

Figure 1

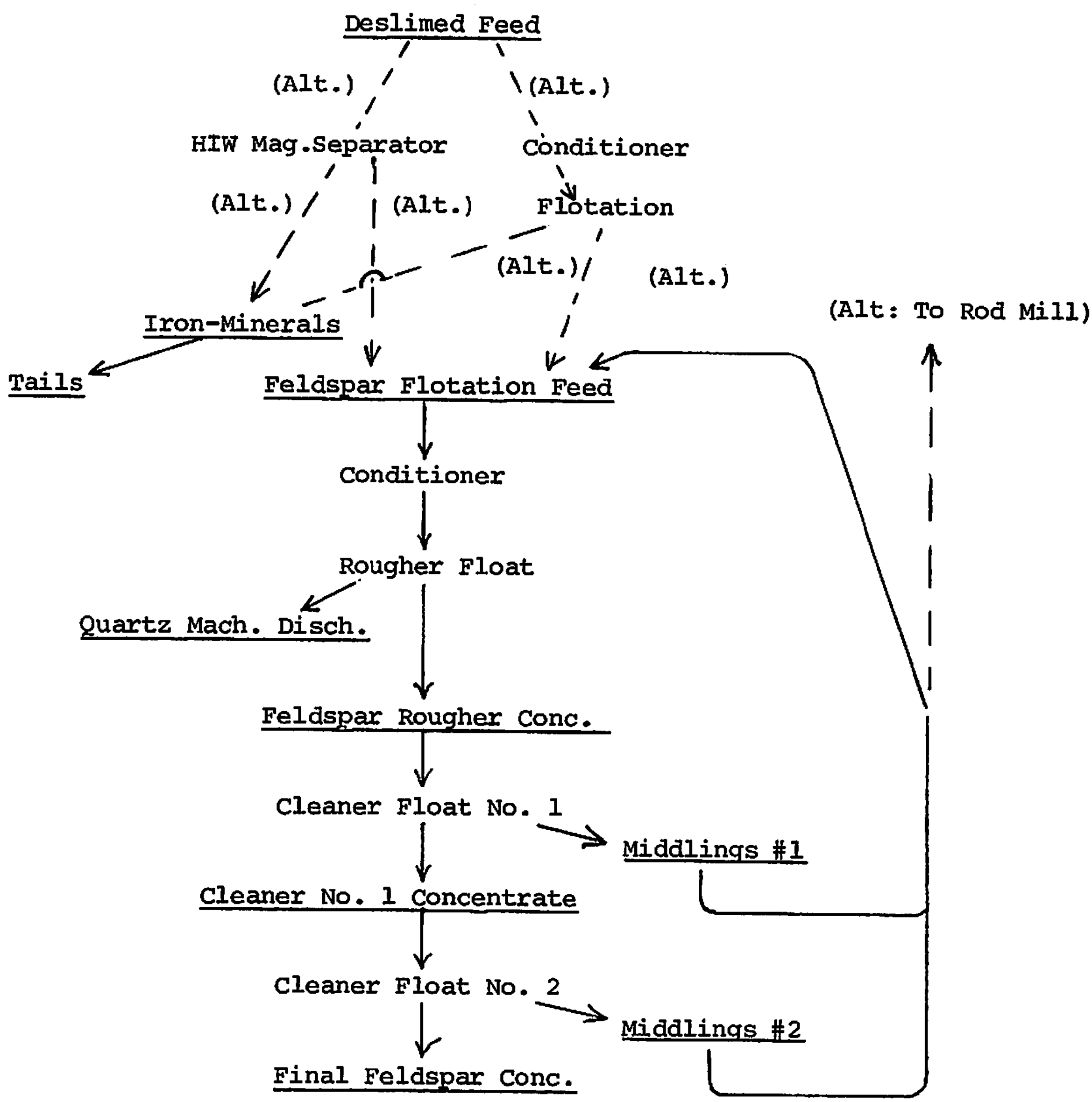
Pilot Plant Flowsheet, Beneficiation of Jordanian Feldspar
(Addition of principal water & reagents not shown)
(Part A: preparation of float feed)



*Trommel screen is integral with mill. Useful for visual control in grinding. Oversize will be close to 10 mesh, of negligible quantity.

Figure 1

Pilot Plant Flowsheet, Beneficiation of Jordanian Feldspar
(Part B: HIW mag. sep. and flotation)



Additional Recommendations

The following additional recommendations are made:

1) A system of comminution should be carefully worked out so as to avoid overgrind, to which this ore appears quite susceptible.

2) One or more manufacturers of high-intensity wet magnetic separators should be asked, before pilot plant operation, to beneficiate a portion of the pilot plant sample and to demonstrate optimum grade and recovery by means of that process. A careful feasibility study should then be made to determine the practicality of HIW magnetic separation vs. iron mineral flotation in the Jordanian setting, and a pilot plant flowsheet set up based on the final decision.

3) A mineralogical appraisal should be made of individual thin-sections from various potential mine sites, and this information used, if possible, to assist in choosing the plant head feed.

4) Additional bench tests should be conducted on the pilot plant feed to determine minimum attrition-scrubbing necessary and to explore avenues toward possible reduction of amine collector in the feldspar flotation.

5) An attempt should be made to find end-uses for these products:

   a) Iron-mineral concentrate

   b) Minus 200 mesh quartz

   c) Minus 325 mesh slimes

6) It should be decided to what extent the re-circulation of water is desirable in the final plant flowsheet, and to

what extent this should be proved out in preceding bench tests and pilot plant runs. This matter is also related to iron mineral flotation vs. magnetic separation.

7) Regarding operation of a pilot plant, the priority of the following objectives should be established:

   a) Production of concentrate samples of acceptable grade for trial offerings to potential users.

   b) Exploration of alternative features of a flowsheet.

   c) Establishment of optimum features of a final flowsheet pattern.

   Establishment of priorities is more important when the supply of pilot plant feed is limited.

8) To operate a pilot plant using 200 pounds per hour of head feed (a minimum figure for the MRL), a pilot plant sample weighing preferably 8000 pounds is asked for - or, at a minimum, 6000 pounds. This quantity will permit a modest amount of checking variables.

9) The pilot plant sample should preferably be sent to the MRL with minimum possible crushing: perhaps minus 2-inch or minus 3-inch size.

10) If reagentized feldspar concentrate from a pilot plant operation is to be submitted for ceramic trial applications, it should be made wettable. This is usually done by agitation with, or addition of, NaOH.

   The MRL is capable of fine-grinding feldspar if that is desired. It has a continuous air-swept pebble mill with ceramic lining.