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LOWER MISSISSIPPI RIVER TERRACE SANDS AS A COMMERCIAL SOURCE OF FELDSPAR

H. P. Ehrlinger III and H. W. Jackman

ABSTRACT

Large deposits of low-grade feldspar sands, a potential source of the mineral feldspar, are present in five general areas in Illinois, but no feldspar is being produced commercially in the state. Feldspar for industrial use is imported from other states.

The second in a series describing Illinois feldspar deposits and the methods used in Illinois State Geological Survey laboratories to produce commercial concentrates of feldspar, this report is concerned with the sands of the lower Mississippi River terrace and floodplains in southwestern Illinois, below the mouth of the Missouri River. Tests indicate that feldspar concentrates of commercial grade can be made from these sands.

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INTRODUCTION

The glass and ceramic industries of Illinois use large quantities of feldspar, including significant tonnages in the manufacture of fiberglass and glass wool insulation. Smaller quantities are used in scouring powders, poultry and bird seed formulations, and in filters.

Although the presence of feldspar in certain Illinois sands has been recognized for many years, none of the feldspar used by Illinois industries is being produced in the state, most of it being shipped from the major feldspar-producing states, North Carolina and South Dakota. The Illinois State Geological Survey published a report in 1942 by Willman, "Feldspar in Illinois Sands," that described the localities, quantities, and qualities of the Illinois feldspar deposits. A more recent study by Hunter (1965) described the petrography of some of the deposits. Both reports served as a basis for this study.

Current feldspar research began in 1966 and is being made to determine where recoverable feldspar occurs in sands in concentrations sufficient to justify commercial development, whether acceptable products can be derived from these sands, whether the feldspar can be produced at a reasonable cost, and whether the by-products that result from feldspar recovery have commercial value.

Five general areas in Illinois (fig. 1) have feldspar-bearing sands of sufficiently high quality and in large enough quantity to be considered as potential industrial sources of feldspar—(1) the Kankakee River area, (2) the Mississippi River area north of the mouth of the Missouri River, (3) the Mississippi River area south of the mouth of the Missouri River, (4) the Green

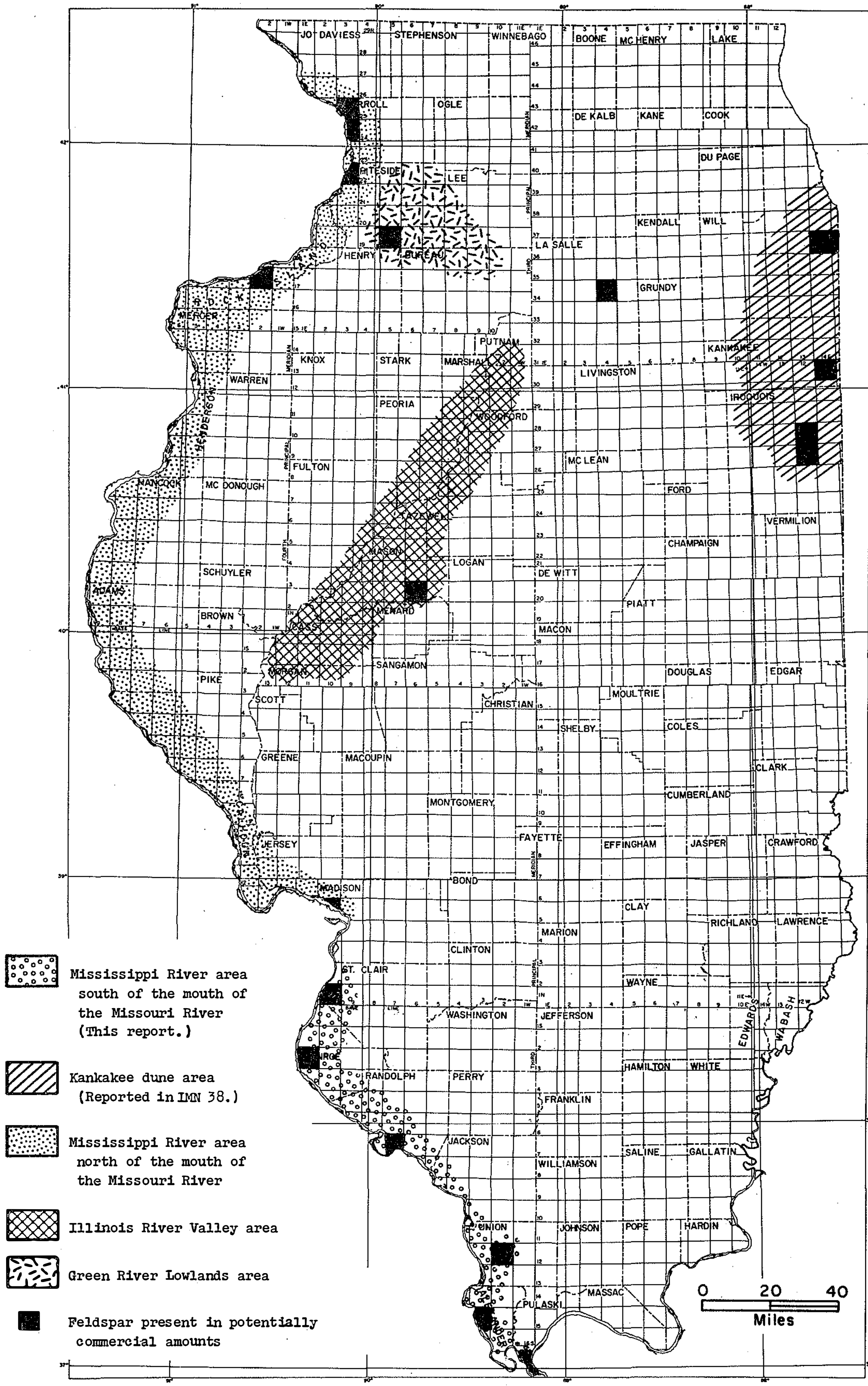

Fig. 1 - Illinois townships in which sands are reported to contain more than 20 percent feldspar.

River Lowland, and (5) selected localities on the Illinois River Valley terraces. The feldspar sands of the Kankakee River area were described in Industrial Minerals Notes 38, published in July 1969. This report, the second of the series, pertains only to the lower Mississippi River terrace and floodplain sands of Monroe and St. Clair Counties, but the sands of the rest of this area show similar characteristics. The feldspar resources of the other three areas will be discussed in subsequent Industrial Minerals Notes.

LOCATION OF DEPOSITS SAMPLED

The samples examined in this study were taken adjacent to and just below East St. Louis in western St. Clair County and farther south in Monroe County. One sample, designated as "East Carondelet" for this report, was obtained from the terrace several hundred feet north of the old Davis Street ferry station, 0.7 miles northwest of the Gulf, Mobile, and Ohio Railroad grade crossing in East Carondelet. Two samples were obtained near Harrisonville Landing in extreme western Monroe County. The sample designated "Harrisonville I" came from a sand island in the Mississippi River, and "Harrisonville II" was taken from the terrace immediately adjacent to the river at the end of the road, 0.8 miles west of Harrisonville at the Riverside Sportsmen's Club.

GEOLOGICAL DESCRIPTION OF AREA

The Mississippi River sources were described by Willman, in a report now out of print (1942, p. 50-51), as follows:

> Enormous quantities of sand and gravel occur at many places along Mississippi River, the gravel principally along or near the deeper channels of the river and the sand in bars both in the river and along its shores. Many sand bars are exposed during intervals of low water and their location is shown on various river maps and the more recent topographic maps, especially those of the Keithsburg, Oquawka, Keokuk, Quincy, Barry, Nebo, Hardin, St. Charles, Granite City, Cahokia, Kimmswick, Crystal City, Renault, Chester, Altenburg, and Thebes quadrangles. To divert the currents into the major channels and maintain a sufficient depth of water for navigation, jetties have been built at many places along the river (many since the above maps were published). Behind these jetties immense quantities of sand have accumulated, and at favorable locations such deposits would probably be replaced almost as fast as removed. Sand and gravel have been dredged from the river bed at many places for use principally in the building industry.
>
> Grain size—Sand deposits of almost any grain size desired can be found along the river.... Medium- and coarse-grained sand is available almost continuously along the river. The fine-grained sands appear to be more abundant south of East St. Louis. Very large bars, of which at least the upper few feet are fine-grained sands, occur along the river west of Valmeyer, near Chester, south of Thebes, and elsewhere along the river. The sands vary in content of material passing 270-mesh, some of the very fine-grained sands

being especially silty. However, many deposits contain little silt, and 9 of the 13 samples contain less than 1 percent of material finer than 270-mesh.

Composition—The Mississippi River sands contain more feldspar than sands in the other rivers and average higher than any other type of sand in Illinois. The 8- and 270-mesh fraction of 13 samples of Mississippi River sand averaged 25 percent feldspar, ranging from 16 to 34 percent. The six samples of sand from below East St. Louis contain more feldspar than the samples from up the valley, averaging 30 percent and ranging from 26 to 34 percent. Although this may be in part attributed to the finer-grain size of the sands south of East St. Louis, it appears to be a general characteristic inasmuch as a sample of coarse pebbly sand collected near Harrisonville, east of Valmeyer, is 89 percent coarser than 48-mesh and contains 26 percent feldspar.

The Mississippi River sands are generally slightly calcareous. Two samples are noncalcareous but the remaining samples average about 2 percent soluble in acid. Some of the acid-soluble material, perhaps as much as 1 percent, is probably iron oxide and soluble minerals other than carbonates. The maximum amount soluble was 5 percent.

Figure 2 shows the general area referred to in Willman's report; the localities sampled for this study are indicated by numbered boxes.

TEST PROCEDURE

The samples tested were found to be essentially the same as those described by Willman and by Hunter. The sands were similar mineralogically to those being treated commercially on the Pacific Coast (Baarson, 1962) and to those studied from the Kankakee area (Ehrlinger, ten Kate, and Jackman, 1969). The beneficiation procedure followed was based on that used by Baarson, but it incorporated modifications introduced for treating the Kankakee sands. The only major difference between the sands of the Kankakee and Mississippi areas is the higher calcium carbonate content in the latter, which requires slightly more sulfuric acid for neutralization. The schematic flowsheet in figure 3 shows the beneficiation procedure.

Optimum assays and recoveries of feldspar from the sand samples, as well as by-products obtainable, are shown in tables 1 to 3. The tables also present the treatment conditions and the reagents consumed during treatment.

Only the rougher (primary) feldspar concentrate was ground during these tests. Feldspar recovery would probably be increased substantially by grinding the rougher tailing and returning the ground product to the head of the circuit to be reprocessed; however, such a practice would probably price the resultant product out of the present market.

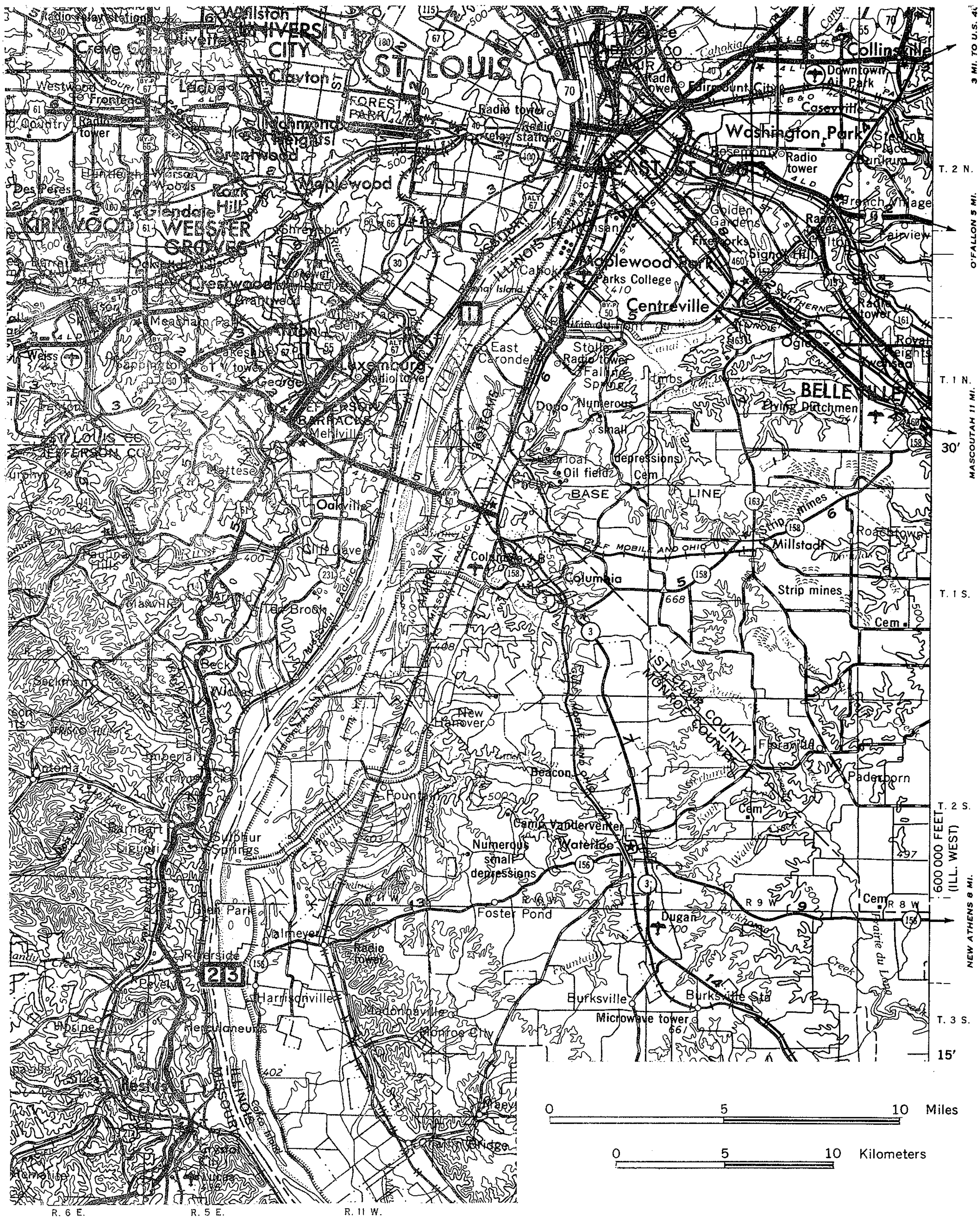

Fig. 2 - Area from which samples were taken. Sampling points are indicated by boxed numbers. (Map based on U. S. Geological Survey topographic map of the St. Louis area.

DESCRIPTION OF TESTS

The primary purpose of the feldspar beneficiation tests is the reduction of iron oxide, titanium oxide, and quartz, with a resultant increase in the percentage of aluminum oxide in the sand. Numerous steps are shown (fig. 3) to point out that each unit operation is a step toward these ends. In practice some of these steps would be combined. Detailed results of each step of the beneficiation process, including assays, weights, and recoveries for each of the three samples tested, are shown in tables 1, 2, and 3.

All the iron oxides are shown in the tables as Fe_2O_3; however, in all probability they occur as magnetite (Fe_3O_4), limonite ($HFeO_2$), or as part of the ilmenite ($FeTiO_3$), rather than as pure hematite (Fe_2O_3). All the titanium is shown by its characteristic chemical analysis, TiO_2, even though it occurs as ilmenite ($FeTiO_3$) and leucoxene (an alteration product) rather than as rutile (TiO_2).

Test 1—East Carondelet Terrace Sands

To remove clay and staining materials from the sand grains, terrace sands from East Carondelet were subjected to attrition without reagents, deslimed, attrited with a small quantity of sulfuric acid (1.0 pound per ton), deslimed again, attrited with 1.0 pound per ton of sodium hydroxide, and deslimed again. Table 1, test A, shows that the iron oxide content in the sands was reduced from 1.21 percent to 0.94 percent, a reduction of 24.8 percent, while only 3.72 percent of the initial weight of the sample and 6.3 percent of the original alumina were lost.

Test B of table 1 shows the subsequent effect of gravity and magnetic separations upon the deslimed sands. Gravity concentration removed another 4.54 percent of the weight of the sample, including 42.8 percent of the titanium oxide and 13.5 percent of the iron oxide. The magnetic concentration removed an additional 12.52 percent of the weight, including 33.9 percent of the titanium oxide and 42.7 percent of the iron oxide.

After the removal of the slimes, the heavy minerals, and the magnetic minerals, 79.22 percent of the original weight remained. Only 10.9 percent of the original titanium oxide and 19.0 percent of the original iron oxide remained in the beneficiated sand; these amounts constituted 0.03 and 0.29 percent, respectively, of the product. Such a product has been used in other midwestern and western states to meet the specifications of a number of industries.

The next step in the process was flotation to reduce the silica content in the sand and produce a high grade feldspar concentrate. First, an iron concentrate was removed, which took out more of the iron oxide and calcium. The feldspar was then floated from the remaining sand. This product was ground lightly to expose fresh feldspar surfaces. Additional flotation and magnetic cleaning further beneficiated the sand, leaving a high grade feldspar concentrate that could be used in all but the very purest glass formulations. A silica concentrate of questionable value remained as a tailing from the feldspar flotation.

linois State Geological Survey, 1969)

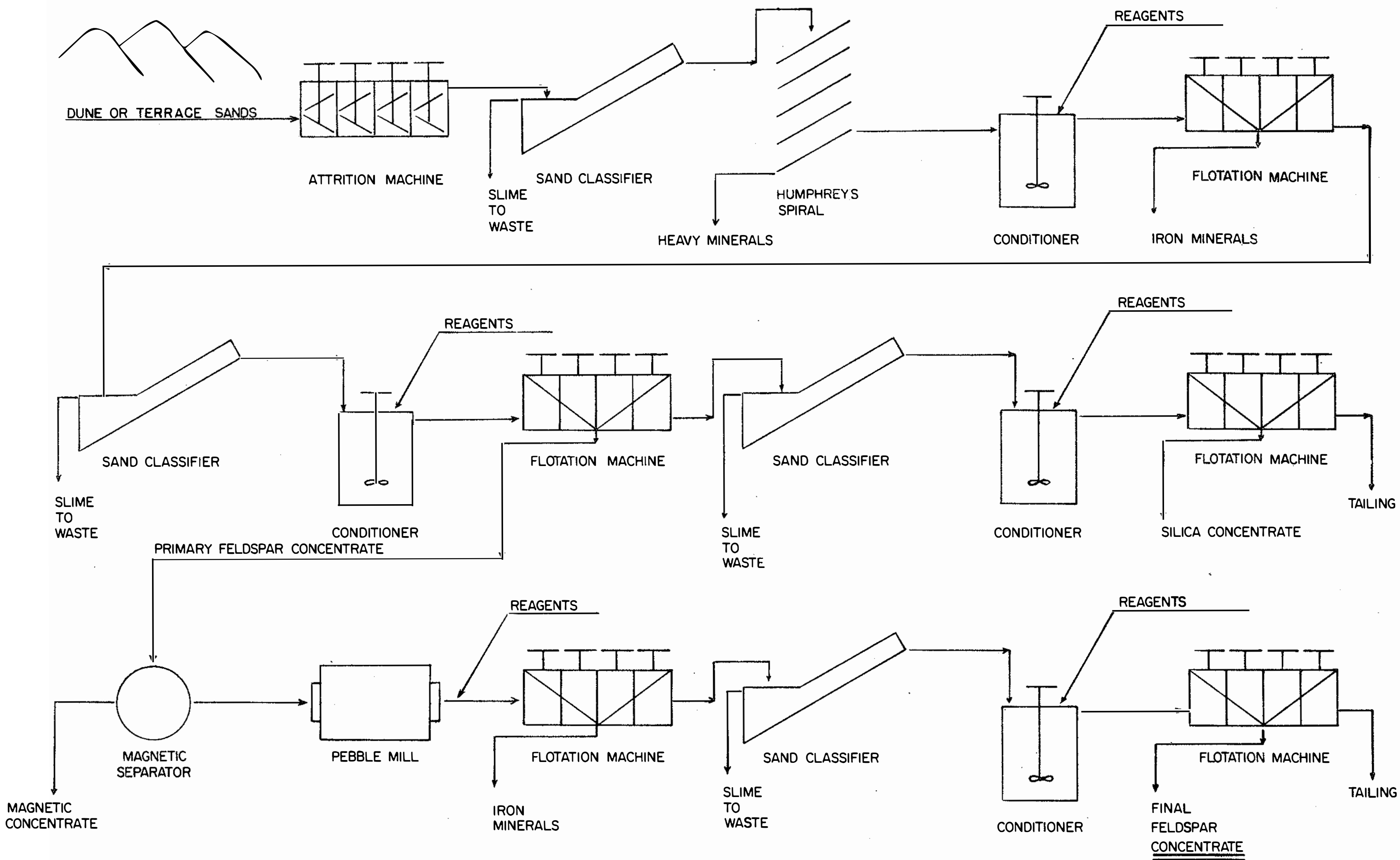

Fig. 3 - Schematic flowsheet for flotation of feldspar from Illinois sands.

The chemical analyses of the mix of silica and feldspar concentrate from this test follow:

Sample	Product	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2
15	Mix	1.74	1.79	0.75	6.92	87.06	0.29	0.03
21	Final concentrate	5.70	6.01	2.49	21.80	67.40	0.22	0.01

Test 2—Harrisonville I Sand Bar Sands

The procedure used with the Harrisonville I sample was similar to that just described for the East Carondelet sample, except for the elimination of the first step involving attrition without a reagent. Acid scrubbing was substituted as the first beneficiation step, and the steps are shown in table 2. As before, two saleable products were prepared, the first a "mix" of feldspar and silica, and the other a final feldspar concentrate. Analyses of these products are as follows:

Sample	Product	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2
39	Mix	1.87	1.67	0.89	6.89	85.81	0.32	0.05
45	Final concentrate	5.98	5.81	2.61	20.90	61.30	0.26	0.03

Test 3—Harrisonville II Terrace Sands

The Harrisonville II sample of feldspar-bearing sand was processed in a manner identical to that used on the preceding sample (table 3). Two saleable products were obtained, the analyses of which are shown below:

Sample	Product	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2
61	Mix	1.71	1.53	0.96	7.06	84.51	0.17	0.02
67	Final concentrate	4.95	4.85	2.37	19.90	64.00	0.20	0.01

Tests for Minor Elements

Selected samples were analyzed for minor constituents, in addition to the K_2O, Na_2O, CaO, Al_2O_3, SiO_2, Fe_2O_3, and TiO_2 determined on all samples used in these tests. Samples examined were Nos. 50, 52, 55, 62, and 67, each of which showed MnO, P_2O_5, SO_3, and ignition loss in very minor amounts. All except sample 67 (final feldspar concentrate) also contained MgO. The samples were also examined by optical emission spectroscopy for lithium, arsenic, lead, tin, bismuth, gallium, germanium, barium, molybdenum, vanadium, indium, cadmium, silver, zinc, cobalt, nickel, strontium, zirconium, and beryllium, but none of these elements was found in amounts greater than 1000 ppm (0.1 percent). Elements sought by neutron activation analysis but not found at 100 ppm (0.1 percent) were gold, arsenic, antimony, gallium, lanthanum, scandium, tungsten, tantalum, bromine, silver, indium, platinum, and cobalt. There are no rare or minor elements present that would either add to or detract from the value of the feldspar.

SUMMARY AND CONCLUSIONS

Illinois sand deposits in the lower Mississippi River terraces contain up to 34 percent feldspar. By using established techniques such as scrubbing (attrition), gravity separation, and magnetic separation, a low-iron, feldspar-quartz "mix" can be made that should meet the requirements of many industries that use such a "mix" in their glass tank feed. Further treatment by flotation yields a product that would be competitive with some of the commercial feldspars at present on the market.

The locations of the sand deposits tested are near existing railroad facilities and are less than 50 miles from glass-making plants in the Greater St. Louis Area.

The tables on the following pages show the chemical composition and recoveries from each of the feldspar-containing sands tested at the various stages of beneficiation.

Acknowledgments

The Analytical Chemistry Section of the Illinois State Geological Survey made the numerous and varied chemical analyses called for in this study. Members of the Industrial Minerals and Stratigraphy Sections of the Survey provided constructive suggestions.

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TABLE 1—EAST CARONDELET TERRACE SANDS

Test A—Desliming Treatment

No.	Product	Dry Weight Grams	% Total	Assays (%) K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Recoveries (% of sample) K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2
1.	Feed	1,996.9	100.00	1.91	1.84	1.17	7.89	82.94	1.21	0.19	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2.	Primary slime	16.0	0.80	2.19	1.06	2.14	12.30	65.90	5.39	0.67	0.9	0.5	1.5	1.2	0.6	3.6	2.9
*3.	Feed minus primary slime	1,980.9	99.20	1.90	1.84	1.16	7.85	83.07	1.17	0.18	99.1	99.5	98.5	98.8	99.4	96.4	97.1
4.	Acid slime	50.3	2.52	2.52	1.36	4.04	13.80	53.70	8.88	0.59	3.3	1.9	8.7	4.4	1.6	18.5	8.0
*5.	Feed minus two slimes	1,930.6	96.68	1.89	1.86	1.09	7.70	83.84	0.97	0.17	95.8	97.6	89.8	94.4	97.8	77.9	89.1
6.	Alkali slime	8.0	0.40	2.83	2.55	0.94	13.80	56.40	8.11	0.70	0.6	0.6	0.3	0.7	0.3	2.7	1.5
*7.	Feed minus three slimes	1,922.6	96.28	1.88	1.85	1.09	7.67	83.95	0.94	0.17	95.2	97.0	89.5	93.7	97.5	75.2	87.6
*	Combined slime (2 + 4 + 6)	74.3	3.72	2.48	1.42	3.30	13.48	56.61	8.05	0.62	4.8	3.0	10.5	6.3	2.5	24.8	12.4

* Calculated product

Reagents added	Time in circuit
To primary attrition - none	10 minutes
To acid attrition - 1.0 lbs. H_2SO_4 per ton	10 minutes
To alkaline attrition - 1.0 lbs NaOH per ton	10 minutes

TABLE 1—EAST CARONDELET TERRACE SANDS

Test B—Gravity and Magnetic Treatment of the Deslimed Sands

No.	Product	Dry weight		Assays (%)							Recoveries (% of sample)						
		Grams	% Total	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2
* 7.	Deslimed feed	1,922.6	96.28	1.88	1.85	1.09	7.67	83.95	0.94	0.17	95.2	97.0	89.5	93.7	97.5	75.2	87.6
* 8.	Gravity concentrate	90.8	4.54	1.20	1.49	4.29	7.48	75.02	3.59	1.75	2.9	3.7	16.6	4.3	4.1	13.5	42.8
9.	Gravity magnetics	28.4	1.42	1.46	1.53	6.85	10.00	52.44	10.80	5.13	1.1	1.2	8.3	1.8	0.9	12.7	39.2
10.	Gravity nonmagnetics	62.4	3.12	1.09	1.47	3.12	6.33	85.30	0.30	0.21	1.8	2.5	8.3	2.5	3.2	0.8	3.6
*11.	Deslimed feed minus gravity concentrate (8)	1,831.8	91.74	1.92	1.87	0.93	7.68	84.40	0.81	0.09	92.3	93.3	72.9	89.4	93.4	61.7	44.8
*12.	Magnetic rougher concentrate	250.0	12.52	3.06	2.39	2.05	12.47	67.56	4.12	0.50	20.1	16.3	21.9	19.8	10.2	42.7	33.9
13.	Magnetic cleaner concentrate	199.4	9.99	3.22	2.51	2.23	13.13	64.33	4.87	0.59	16.9	13.6	19.0	16.6	7.8	40.3	31.7
14.	Magnetic cleaner tailing	50.6	2.53	2.42	1.94	1.32	9.84	80.30	1.16	0.16	3.2	2.7	2.9	3.2	2.4	2.4	2.2
*15.	Deslimed feed minus gravity and magnetic concentrate (flotation feed)	1,581.8	79.22	1.74	1.79	0.75	6.92	87.06	0.29	0.03	72.2	77.0	51.0	69.6	83.2	19.0	10.9

* Calculated product

Remarks: Sample nos. 9 + 10 = Sample no. 8; Sample nos. 13 + 14 = Sample no. 12.

Gravity separation by Vanning Plaque

Magnetic separations by Carpco Induced Roll Magnetic Separator

TABLE 1—EAST CARONDELET TERRACE SANDS

Test C—Flotation Treatment of the Deslimed Sands After Removal of High Gravity and Magnetic Minerals

No.	Product	Dry weight: Grams	Dry weight: % Total	Assays (%): K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Recoveries (% of sample): K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2
*15.	Flotation feed	1,581.8	79.22	1.74	1.79	0.75	6.92	87.06	0.29	0.03	72.2	77.0	51.0	69.6	83.2	19.0	10.9
16.	First iron concentrate	37.6	1.88	2.22	1.53	4.49	8.22	76.10	0.35	0.09	2.2	1.6	7.2	2.0	1.7	0.5	0.9
*17.	Feldspar rougher concentrate	615.1	30.81	4.09	4.37	1.63	15.64	73.81	0.33	0.03	66.1	73.1	43.0	61.1	27.4	8.5	5.2
18.	Refloat iron concentrate	25.7	1.29	4.85	3.48	1.62	16.20	67.50	0.92	0.21	3.3	2.4	1.8	2.6	1.0	1.0	1.5
*19.	Refloat feldspar concentrate	381.0	19.08	5.55	6.07	2.44	21.35	66.97	0.34	0.03	55.6	63.0	39.7	51.7	15.4	5.4	2.6
20.	Feldspar magnetics	71.1	3.56	4.92	6.34	2.20	19.40	65.10	0.87	0.09	9.2	12.3	6.7	8.8	2.8	2.6	1.7
21.	FINAL FELDSPAR CONCENTRATE	309.9	15.52	5.70	6.01	2.49	21.80	67.40	0.22	0.01	46.4	50.7	33.0	42.9	12.6	2.8	0.9
22.	Cleaner tailing	208.4	10.44	1.32	1.36	0.17	5.14	87.10	0.24	0.02	7.2	7.7	1.5	6.8	11.0	2.1	1.1
23.	Silica concentrate	643.1	32.21	0.04	0.02	0.02	0.48	97.10	0.11	0.01	0.7	0.3	0.6	2.0	37.8	2.9	1.7
24.	Rougher tailing	286.0	14.32	0.43	0.26	0.02	2.49	94.40	0.60	0.04	3.2	2.0	0.2	4.5	16.3	7.1	3.1

* Calculated product

Remarks: Sample nos. 16 + 17 + 23 + 24 = Sample no. 15; Sample nos. 18 + 19 + 22 = Sample no. 17; and Sample nos. 20 + 21 = Sample no. 19.

Reagents added (lbs/ton original sand) to flotation circuit

To primary iron:
- 3.4 H_2SO_4
- 0.4 Fuel oil
- 0.8 AC 801
- 0.4 AC 825
- 0.15 AC B-70

To primary feldspar:
- 1.0 HF, 48%
- 0.18 Kerosene
- 0.37 AI Armac T
- 0.15 AC B-70

To silica:
- 0.3 NaOH
- 1.0 AI Neo-Fat
- 0.1 AC B-70

To refloat iron:
- 0.7 H_2SO_4
- 0.2 Fuel oil
- 0.4 AC 801
- 0.2 AC 825

To refloat feldspar:
- 0.08 HF, 48%
- 0.06 Kerosene
- 0.14 Armac T
- 0.02 AC B-70

pH of circuits
- Iron 2.5
- Feldspar 2.8
- Silica 9.0

All primary flotation times = 8 minutes

Regrind rougher concentrate without reagents 10 minutes

TABLE 2—HARRISONVILLE I SAND BAR SANDS

Test A—Desliming Treatment

No.	Product	Dry weight		Assays (%)							Recoveries (% of sample)						
		Grams	% Total	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2
25.	Feed	1,995.7	100.00	1.94	1.73	1.41	7.70	81.91	1.24	0.19	100.0	100.0	100.0	100.0	100.0	100.0	100.0
26.	Acid slime	65.4	3.28	2.36	1.19	2.89	13.00	58.90	7.32	0.66	4.0	2.3	6.7	5.5	2.4	19.4	11.5
*27.	Feed minus acid slime	1,930.3	96.72	1.93	1.75	1.36	7.52	82.69	1.03	0.17	96.0	97.7	93.3	94.5	97.6	80.6	88.5
28.	Alkali slime	23.4	1.17	2.65	2.40	1.90	13.50	59.90	7.66	0.68	1.6	1.6	1.6	2.1	0.9	7.2	4.2
*29.	Feed minus two slimes	1,906.9	95.55	1.92	1.74	1.36	7.45	82.97	0.95	0.17	94.4	96.1	91.7	92.4	96.7	73.4	84.3
*	Combined slime (26 + 28)	88.8	4.45	2.44	1.51	2.63	13.13	59.16	7.41	0.67	5.6	3.9	8.3	7.6	3.3	26.6	15.7

* Calculated product

Reagents added	Time in circuit
To acid attrition - 1.0 lbs H_2SO_4 per ton	10 minutes
To alkaline attrition - 1.0 lbs NaOH per ton	10 minutes

TABLE 2—HARRISONVILLE I SAND BAR SANDS

Test B—Gravity and Magnetic Treatment of the Deslimed Sands

No.	Product	Dry weight		Assays (%)							Recoveries (% of sample)						
		Grams	% Total	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2
*29.	Deslimed feed	1,906.9	95.55	1.92	1.74	1.36	7.45	82.97	0.95	0.17	94.4	96.1	91.7	92.4	96.7	73.4	84.3
*30.	Gravity concentrate	124.2	6.22	1.08	1.49	5.24	6.44	72.69	3.27	1.19	3.4	5.3	23.0	5.2	5.5	16.4	39.1
31.	Gravity magnetics	45.9	2.30	1.28	1.46	6.58	8.36	60.40	8.12	2.67	1.5	1.9	10.7	2.5	1.7	15.1	32.5
32.	Gravity nonmagnetics	78.3	3.92	0.96	1.51	4.45	5.32	79.90	0.42	0.32	1.9	3.4	12.3	2.7	3.8	1.3	6.6
*33.	Deslimed feed minus gravity concentrate (30)	1,782.7	89.33	1.98	1.76	1.09	7.52	83.68	0.79	0.10	91.0	90.8	68.7	87.2	91.2	57.0	45.2
*34.	Magnetic rougher concentrate	328.3	16.45	2.48	2.15	1.96	10.27	74.26	2.88	0.29	21.0	20.5	22.8	21.9	15.0	38.1	25.4
35.	Magnetic recleaner concentrate	116.2	5.82	3.01	2.72	2.82	13.50	61.80	5.99	0.57	9.0	9.2	11.6	10.2	4.4	28.1	17.6
36.	Magnetic recleaner tailing	72.1	3.61	2.83	2.27	1.64	11.70	71.50	2.55	0.33	5.3	4.7	4.2	5.5	3.2	7.4	6.3
*37.	Magnetic cleaner concentrate	188.3	9.43	2.94	2.55	2.37	12.81	65.51	4.67	0.48	14.3	13.9	15.8	15.7	7.6	35.5	23.9
38.	Magnetic cleaner tailing	140.0	7.02	1.86	1.61	1.41	6.86	86.00	0.46	0.04	6.7	6.6	7.0	6.2	7.4	2.6	1.5
*39.	Feed minus slime, gravity, and magnetic concentrates	1,454.4	72.88	1.87	1.67	0.89	6.89	85.81	0.32	0.05	70.0	70.3	45.9	65.3	76.2	18.9	19.8

* Calculated product

Remarks: Sample nos. 31 + 32 = Sample no. 30; Sample nos. 37 + 38 = Sample no. 34; Sample nos. 35 + 36 = Sample no. 37.

Gravity separation by Vanning Plaque

Magnetic separations by Carpco Induced Roll Magnetic Separator

TABLE 2—HARRISONVILLE I SAND BAR SANDS

Test C—Flotation Treatment of the Deslimed Sands After the Removal of High Gravity and Magnetic Minerals

No.	Product	Dry weight Grams	Dry weight % Total	Assays (%) K_2O	Assays (%) Na_2O	Assays (%) CaO	Assays (%) Al_2O_3	Assays (%) SiO_2	Assays (%) Fe_2O_3	Assays (%) TiO_2	Recoveries (% of sample) K_2O	Recoveries (% of sample) Na_2O	Recoveries (% of sample) CaO	Recoveries (% of sample) Al_2O_3	Recoveries (% of sample) SiO_2	Recoveries (% of sample) Fe_2O_3	Recoveries (% of sample) TiO_2
*39.	Flotation feed	1,454.4	72.88	1.87	1.67	0.89	6.89	85.81	0.32	0.05	70.0	70.3	45.9	65.3	76.2	18.9	19.8
40.	First iron concentrate	5.0	0.25	1.05	0.67	19.80	4.62	27.00	0.96	0.23	0.1	0.1	3.5	0.2	0.1	0.2	0.3
*41.	Feldspar rougher concentrate	388.7	19.47	5.05	4.94	2.34	17.68	65.81	0.37	0.06	50.6	55.7	32.2	44.7	15.5	5.8	6.3
42.	Refloat iron concentrate	24.1	1.21	4.49	4.15	3.33	15.40	60.30	1.26	0.25	2.8	2.9	2.9	2.4	0.9	1.2	1.6
*43.	Refloat feldspar concentrate	290.1	14.53	5.92	5.75	2.60	20.68	61.52	0.31	0.04	44.3	48.4	26.7	39.0	10.8	3.6	3.3
44.	Feldspar magnetics	31.8	1.59	5.47	5.31	2.52	18.90	63.30	0.72	0.14	4.5	4.9	2.8	3.9	1.2	0.9	1.2
45.	FINAL FELDSPAR CONCENTRATE	258.3	12.94	5.98	5.81	2.61	20.90	61.30	0.26	0.03	39.8	43.5	23.9	35.1	9.6	2.7	2.1
46.	Cleaner tailing	74.5	3.73	1.82	2.03	1.00	6.71	84.30	0.32	0.07	3.5	4.4	2.6	3.3	3.8	1.0	1.4
47.	Silica concentrate	197.7	9.91	0.37	0.16	0.11	1.79	93.50	0.13	0.02	1.9	0.9	0.8	2.3	11.3	1.0	1.1
48.	Rougher tailing	863.0	43.25	0.78	0.55	0.31	3.22	93.62	0.34	0.05	17.4	13.6	9.4	18.1	49.3	11.9	12.1

* Calculated product

Remarks: Sample nos. 40 + 41 + 47 + 48 = Sample no. 39; Sample nos. 42 + 43 + 46 = Sample no. 41; and Sample nos. 44 + 45 = Sample no. 43.

Reagents added (lbs/ton original sand) to flotation circuit

To primary iron:
- 3.4 H_2SO_4
- 0.4 Fuel oil
- 0.8 AC 801
- 0.4 AC 825
- 0.15 AC B-70

To primary feldspar:
- 1.0 HF, 48%
- 0.18 Kerosene
- 0.37 AI Armac T
- 0.15 AC B-70

To silica:
- 0.3 NaOH
- 1.0 AI Neo-Fat
- 0.1 AC B-70

To refloat iron:
- 0.7 H_2SO_4
- 0.2 Fuel oil
- 0.4 AC 801
- 0.2 AC 825

To refloat feldspar:
- 0.08 HF, 48%
- 0.06 Kerosene
- 0.14 Armac T
- 0.02 AC B-70

pH of circuits

- Iron 2.5
- Feldspar 2.8
- Silica 9.0

All primary flotation times = 8 minutes

Regrind rougher concentrate without reagents 10 minutes

TABLE 3—HARRISONVILLE II TERRACE SANDS

Test A—Desliming Treatment

		Dry weight		Assays (%)							Recoveries (% of sample)						
No.	Product	Grams	% Total	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2
49.	Feed	1,991.2	100.00	1.95	1.72	1.52	8.31	78.49	1.43	0.25	100.0	100.0	100.0	100.0	100.0	100.0	100.0
50.	Acid slime	129.0	6.48	2.31	1.19	3.12	11.60	59.40	5.81	0.54	7.7	4.5	13.4	9.0	4.9	26.4	13.8
*51.	Feed minus acid slime	1,862.2	93.52	1.93	1.76	1.40	8.09	79.82	1.12	0.23	92.3	95.5	86.6	91.0	95.1	73.6	86.2
52.	Alkali slime	23.5	1.18	2.23	2.55	1.60	10.70	64.10	4.62	0.50	1.3	1.8	1.2	1.5	1.0	3.8	2.3
*53.	Feed minus two slimes	1,838.7	92.34	1.93	1.75	1.40	8.05	80.02	1.08	0.23	91.0	93.7	85.4	89.5	94.1	69.8	83.9
*	Combined slime (50 + 52)	152.5	7.66	2.30	1.40	2.89	11.46	60.12	5.63	0.53	9.0	6.3	14.6	10.5	5.9	30.2	16.1

* Calculated product

Reagents added	Time in circuit
To acid attrition - 1.0 lbs H_2SO_4 per ton	10 minutes
To alkaline attrition - 1.0 lbs NaOH per ton	10 minutes

TABLE 3—HARRISONVILLE II TERRACE SANDS

Test B—Gravity and Magnetic Treatment of the Deslimed Sands

No.	Product	Dry weight		Assays (%)							Recoveries (% of sample)						
		Grams	% Total	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2
*53.	Deslimed feed	1,838.7	92.34	1.93	1.75	1.40	8.05	80.02	1.08	0.23	91.0	93.7	85.4	89.5	94.1	69.8	83.9
*54.	Gravity concentrate	101.4	5.09	1.24	1.41	4.43	6.75	69.15	4.64	2.13	3.3	4.1	14.8	4.1	4.5	16.6	42.7
55.	Gravity magnetics	46.2	2.32	1.40	1.44	5.64	7.92	56.20	9.76	4.37	1.7	1.9	8.6	2.2	1.7	15.9	40.0
56.	Gravity nonmagnetics	55.2	2.77	1.10	1.38	3.41	5.77	80.00	0.36	0.25	1.6	2.2	6.2	1.9	2.8	0.7	2.7
*57.	Deslimed feed minus gravity concentrate (54)	1,737.3	87.25	1.97	1.77	1.23	8.13	80.65	0.87	0.12	87.7	89.6	70.6	85.4	89.6	53.2	41.2
*58.	Magnetic rougher concentrate	425.0	21.34	2.76	2.50	2.06	11.43	68.73	3.02	0.41	30.2	31.0	29.0	29.4	18.6	45.2	34.7
59.	Magnetic cleaner concentrate	244.9	12.30	3.05	2.70	2.39	12.70	62.80	4.44	0.57	19.2	19.3	19.4	18.8	9.8	38.2	27.6
60.	Magnetic cleaner tailing	180.1	9.04	2.37	2.23	1.61	9.69	76.80	1.10	0.20	11.0	11.7	9.6	10.6	8.8	7.0	7.1
*61.	Deslimed feed minus gravity and magnetic concentrate (flotation feed)	1,312.3	65.91	1.71	1.53	0.96	7.06	84.51	0.17	0.02	57.5	58.6	41.6	56.0	71.0	8.0	6.5

*Calculated product

Remarks: Samples nos. 55 + 56 = Sample no. 54; Sample nos. 59 + 60 = Sample no. 58.

Gravity separation by Vanning Plaque

Magnetic separations by Carpco Induced Roll Magnetic Separator

TABLE 3—HARRISONVILLE II TERRACE SANDS

Test C—Flotation Treatment of the Deslimed Sands After Removal of High Gravity and Magnetic Minerals

No.	Product	Dry weight		Assays (%)							Recoveries (% of sample)						
		Grams	% Total	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Fe_2O_3	TiO_2
*61.	Flotation feed	1,312.3	65.91	1.71	1.53	0.96	7.06	84.51	0.17	0.02	57.5	58.6	41.6	56.0	71.0	8.0	6.5
62.	First iron concentrate	20.4	1.02	1.37	1.01	10.30	5.15	57.20	0.53	0.10	0.7	0.6	6.9	0.6	0.7	0.4	0.4
*63.	Feldspar rougher concentrate	552.5	27.75	3.58	3.40	1.79	14.23	72.27	0.18	0.03	50.9	54.9	32.8	47.6	25.6	3.6	3.6
64.	Refloat iron concentrate	16.4	0.82	4.56	2.94	5.48	13.80	58.50	0.82	0.28	1.9	1.4	3.0	1.4	0.6	0.5	0.9
*65.	Refloat feldspar concentrate	372.7	18.72	4.95	4.83	2.37	19.78	64.05	0.22	0.02	47.4	52.5	29.3	44.6	15.3	3.0	1.4
66.	Feldspar magnetics	35.9	1.80	4.97	4.60	2.35	18.70	64.50	0.46	0.10	4.6	4.8	2.8	4.1	1.5	0.6	0.7
67.	FINAL FELDSPAR CONCENTRATE	336.8	16.92	4.95	4.85	2.37	19.90	64.00	0.20	0.01	42.8	47.7	26.5	40.5	13.8	2.4	0.7
68.	Cleaner tailing	163.4	8.21	0.37	0.20	0.10	1.61	92.40	0.02	0.04	1.6	1.0	0.5	1.6	9.7	0.1	1.3
69.	Silica concentrate	499.4	25.09	0.12	0.02	0.00	1.30	95.50	0.07	0.00	1.5	0.3	0.0	3.9	30.5	1.2	0.0
70.	Rougher tailing	240.0	12.05	0.72	0.41	0.24	2.71	92.13	0.33	0.05	4.4	2.8	1.9	3.9	14.2	2.8	2.5

* Calculated product

Remarks: Sample nos. 62 + 63 + 69 + 70 = Sample no. 61; Sample nos. 64 + 65 + 68 = Sample no. 63; and Sample nos. 66 + 67 = Sample no. 65.

Reagents added (lbs/ton original sand) to flotation circuit

To primary iron:
- 3.4 H_2SO_4
- 0.4 Fuel oil
- 0.8 AC 801
- 0.4 AC 825
- 0.15 AC B-70

To primary feldspar:
- 1.0 HF, 48%
- 0.18 Kerosene
- 0.37 AI Armac T
- 0.15 AC B-70

To silica:
- 0.3 NaOH
- 1.0 AI Neo-Fat
- 0.1 AC B-70

To refloat iron:
- 0.7 H_2SO_4
- 0.2 Fuel oil
- 0.4 AC 801
- 0.2 AC 825

To refloat feldspar:
- 0.08 HF, 48%
- 0.06 Kerosene
- 0.14 Armac T
- 0.02 AC B-70

pH of circuits
- Iron 2.5
- Feldspar 2.8
- Silica 9.0

All primary flotation times = 8 minutes
Regrind rougher concentrate without reagents 10 minutes

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