

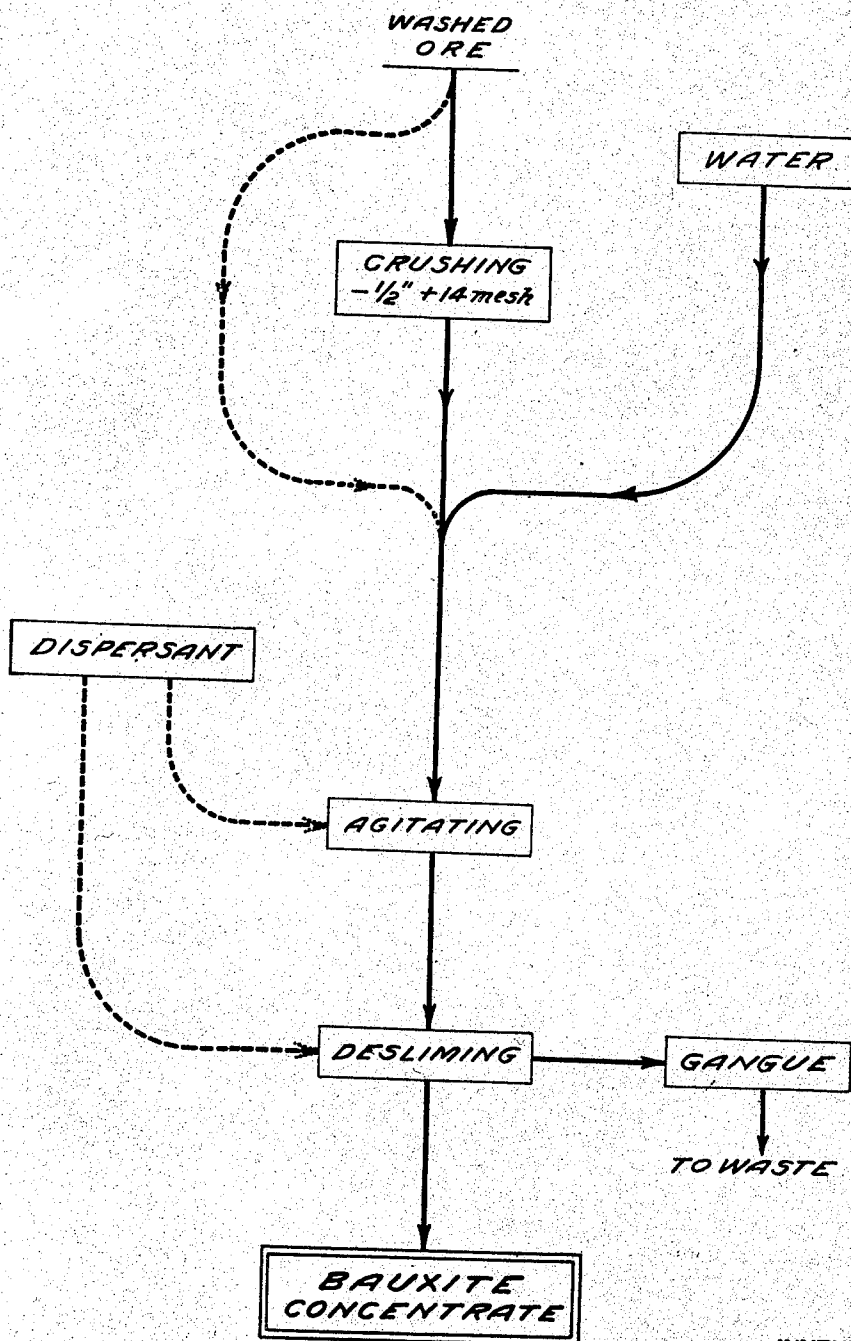
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BAUXITE BENEFICIATION BY HYDRATION OF GANGUE

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BAUXITE BENEFICIATION BY HYDRATION
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This invention relates to beneficiation of low grade bauxite ores and comprises a continuation-in-part of my copending application for U. S. Letters Patent, Serial No. 415,889, filed October 21, 1941.

So called "bauxite" ores, as sources of aluminum material and aluminum chemicals are commercially of great importance. The economic factors involved in the commercial production of these materials have resulted in the fixing of definite minimum requirements for the ore to be used for various purposes. For example, in the manufacture of metallic aluminum, the ore is normally required to assay over 50% Al_2O_3 and less than 7% SiO_2 . In the manufacture of abrasives, the SiO_2 content normally must not exceed 6.5% and the Fe_2O_3 content must be less than 7%. Commercially a premium is usually paid for ores which exceed the minimum specifications.

In the past, deposits of native ore which would meet or better these requirements have been available. However, these deposits of naturally-occurring, high-grade ores are being very rapidly exhausted. As a consequence more attention is being directed to methods and means for utilizing the extensive deposits of lower grade ores which are found in this country, principally in the Arkansas and Appalachian fields.

Since the operations in which these ores are used as raw materials are to a large extent dependent upon the use of ores having the specified grades for satisfactory operation, there is a demand for a suitable process of beneficiating these ores. Because "bauxite" is normally a low-priced ore, such a process in order to be practical must be also relatively simple and cheap to operate. The process of the present invention presents one solution of this problem.

In considering the process of the present invention, an examination of the ore as it is mined is helpful. Actually, the designation "bauxite" ore is usually a misnomer. The principal constituents are generally found to be gibbsite or cillachite ($\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$) and kaolinite



Bauxite ($\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$) may be present in some ore but gibbsite usually is the principal mineral constituent. There usually are present also, comparatively small amounts of iron minerals, such as hematite, limonite, and the like; and less frequently, minerals such as siderite. Titanium minerals are also frequently found, the ore usually assaying from 0.5 to 6.0% TiO_2 . Quartz sand (SiO_2) is occasionally present to the extent of 0.1 to 2.0%.

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Physically, the different bauxite ores resemble each other quite closely. Usually there is a core of gibbsite. In size, these cores may range from very small particles to good sized marbles or larger. These cores are neither perfectly solid nor perfectly smooth. Consequently, a certain amount of gangue is always found to be present in the pits and voids of these cores. A considerably larger portion of gangue adheres firmly to the external surface of the core and the gangue entrapped therein, usually forming a complete covering so that the composite resembles an unfired clay marble. Still a third portion of the gangue comprises a matrix in which the particles and their firmly-adherent portion of gangue are embedded.

If these low grade ores are treated by washing and screening, a part of the gangue which has been designated above as matrix can be readily removed. It will be apparent that its removal will raise the residual alumina-silica ratio. However, with low grade ores, such as those with which the present invention is primarily concerned, this will not ordinarily bring the alumina-silica ratio up to that necessary for an ore which is to be used, for example, in the production of metallic aluminum.

These washing and screening treatments have been used to some extent in foreign countries. Their use in such cases is merely to make a slight saving on the freight charges on export ore. Some savings can be made in this way even in the case of ore which is already of sufficiently high grade for manufacturing purposes. These washing processes have a useful purpose in this field even though the beneficiation is so slight as to seldom warrant the expense of using them solely for the purpose of raising the grade.

That portion of the gangue which adheres to the surface of the core is much more stably held than is the matrix gangue and will withstand considerable rough handling without being released. The gangue which is held in the pits and voids is even more firmly attached. Because some gangue may be present in a bauxite suitable for the production of aluminum products, ore from some deposits can be raised to the necessary grade simply by using the washing and screening methods set forth above. However, as pointed out, the degree of beneficiation which can be obtained is so small that these ores are normally considered as part of the rapidly vanishing high-grade ores. The process of the present invention is concerned only with those ores in which it is necessary to remove substantially all of the matrix and at least a portion of the firmly adherent gangue.

Ordinary methods of beneficiating low grade ores are not particularly well-adapted to the treatment of bauxite. Much of the gangue, particularly that held in the pits and voids, requires extremely fine grinding in order to effect a complete release. After they have been released, the embarrassing feature of the gibbsite, kaolinite and the like having approximately the same specific gravities, prevents acceptable beneficiation by ordinary commercial methods of gravity concentration.

Froth flotation methods suffer from the drawback that most of the available reagents exhibit little selectivity, possibly due to the aluminum content of kaolinite. Such reagents as are sufficiently selective to warrant potential use are expensive and extremely sensitive to the presence of slimes. As a result, the ore must be deslimed very fully, an operation which the similarities in specific gravities makes both difficult and expensive. Successful commercial beneficiation of such ores therefore requires a special procedure adapted for that purpose. As pointed out, in addition to being operable, such processes must also be simple to use and cheap in operation if they are to be suitable for commercial development.

In my copending application 406,533, filed August 12, 1941, I have shown that such low grade ore may be satisfactorily beneficiated into a commercially acceptable grade by a process which comprises preliminarily crushing the ore, soaking the ore for a considerable period, fine crushing the soaked ore, and desliming the crushed ore by wet screening or hydraulic classification. It was pointed out that one of the essential factors was to transform the clay into a physical condition such that it can be separated and removed as slimes by any suitable sizing operation. A soaking period, dependent in length on the nature of the ore and the extent of the preliminary crushing, was employed for this transformation. While extending the soaking period used with a particular ore tended to increase the silica removed in the slimes, it also decreased the over-all recovery of aluminum so that an economic balance between the two factors had to be determined and maintained.

This process using an extended soaking period will produce satisfactory results, but it is economically inconvenient both because of the waiting period involved and the extensive equipment required for storage. In the process of my previous application a material amount of stirring and crushing was necessary after the soaking period and before the desliming procedure in order to insure proper suspension and size grading.

I have now found that if agitation of the ore is carried out during the soaking period the necessary time interval may be shortened to a wholly unexpected degree. With sufficiently violent agitation I obtained in a few minutes results comparable to those obtained with the same ore only after a period of twenty-four to forty-eight hours of soaking without agitation.

This is of great commercial advantage in that it saves both time and storage equipment. In addition, I have found that no subsequent stirring step was necessary as in the case of the soaking without agitation and that the material may be passed directly to the desliming apparatus without any fine crushing. This is also a considerable advantage because of the saving in power and equipment needed for the crushing steps.

The drawing shows a representation of a flow sheet of the process.

In general, the object of the present invention is accomplished by crushing the ore to a size convenient for handling, making it into a pulp with water, agitating the pulp to separate the gangue from the other constituents and desliming the resultant mixture.

In carrying out the process of the present invention, I have found that the preliminary crushing of the ore is relatively unimportant. The principal limitation is that the material be small enough to pass into the apparatus used to carry out the agitation. The process is found to work well with ores having been crushed sufficiently to pass a $\frac{1}{4}$ to $\frac{1}{2}$ inch screen. However, grinding the material to a somewhat smaller size is sometimes beneficial, especially where a relatively large proportion of the gangue is held in the pits and voids of the core.

Grinding the ore to the extent of producing an average particle size less than 14 mesh has been found to yield excessive amounts of gibbsite and/or bauxite fines. The mineral values represented by these fines are subsequently lost in the desliming operation. Consequently, excessive grinding must be avoided. This in itself is a considerable advantage because it eliminates the necessity for grinding the ore to a specific small size as is required in many beneficiating processes.

The present process has an additional advantage in that it is not particularly critical to the amount of water used to dilute the crushed pulp. Only so much as is required for convenient handling is necessary. In general, the more violent the agitation the less water is necessary. This not only makes the process simpler from a practical point of view, but is of considerable importance in that it enables the process to be more readily practical in those regions where process water is scarce.

I have found, however, that the nature and the duration of the agitation is highly important. The greater the violence of agitation the less time is required with any given ore. In general, the agitation may be carried out in any conventional machine including aerators, mechanical stirrers, beaters, ball or rod mills, pumps and the like. However, these machines such as the mills which normally involve grinding or disintegration must be carefully used. Since as pointed out above, an excessive reduction in the average particle size increases the alumina loss in the wet slimes, in using a ball and rod mill for example, the balls and rods should be either entirely eliminated or only one or two inserted to provide a slight agitation with a minimum of reduction in particle size. Good results are obtained by using a mill simply as a rolling drum.

Certain machines such as mechanical-type flotation machines which produce a very violent agitation were found to give equivalent results in a correspondingly shorter time than that required when using a more gentle agitation. Excellent results were obtained, for example, using a Fagregren flotation machine. Favorable ores gave acceptable results in as short a period as one minute. Most of the ores tested required no longer than from 1-5 minutes and only a very few particularly recalcitrant ores required as long as 30 minutes.

Aside from the shortened time period permissible with a flotation machine, they possess a number of other specific advantages. These machines have a tremendous capacity as compared

to other types of stirrers. The necessary amount of water can be, to a large extent, recovered and reused, which would be of advantage in localities where water supply is a serious problem. Again, due to the exceedingly short time period required, no silica gel is formed and does not interfere in the handling of the waste. Nor is the time period required long enough to allow any appreciable hydration of the alumina present, so that there is very little loss in the slimes due to this cause.

After the agitation, the pulp may be directly deslimed either by a wet screening operation or by hydraulic classification. If desired the deslimed sands may be subjected to a tabling operation which will further increase the aluminum ratio by removing a portion of the heavier minerals, such as those of iron or titanium. For abrasive manufacture, the bauxite must give a calcined product containing less than 6.5% silica and less than 7% iron as ferric oxide. My beneficiated bauxite is low enough in silica to enable its being readily brought within these limits by such tabling steps.

While it is not proposed to limit the invention to any particular theory of operation, it is believed that the actual concentration, i. e., the increase of the alumina-silica ratio obtained by the process of the present invention is due to two factors. The first of these is the separation of a sufficient amount of adhering gangue from the mineral by the action of self-attrition which occurs during the agitating step. Both bauxite and gibbsite are slightly harder than the silicate-bearing gangue. Therefore, the gangue is separated from the minerals by the action of the particles one upon the other without materially decreasing the average-particle size of the mineral values themselves. So far as the externally adhering gangue is concerned, the resultant action is comparable to peeling an onion by removing successive external layers.

The second important factor is apparently the causing of the gangue to hydrate to a more readily water dispersible form. This permits the excess adherent gangue to be more readily loosened, and separated from the cleaned mineral values by the action of self-attrition. As distinguished from my previously mentioned, depending application in which the hydration of the gangue is of primary importance, in the present process it appears to be secondary to and in aid of the action of self-attrition.

The invention will be described in greater detail in conjunction with the following specific examples which represent the treatment of typical low grade bauxite ores. These examples are merely illustrative and are not meant to limit the scope of the invention. The parts are by weight.

EXAMPLE 1

In order to test the effect of preliminary crushing before subjecting the ore to the agitating and desliming operations, a number of samples of low-grade bauxite ore from Arkansas were stage-crushed through several designated screen sizes. The crushed ore was diluted to approximately 35% solids with water and subjected to a 5 minute treatment in a Fagregren flotation machine from which alternate bars of the rotor and stator were removed. The air inlet was closed. The agitated materials were wet screened with a separation at plus 65 mesh. The undersize portion was settled with sodium silicate as a dispersant

for one minute, decanted and the residue washed twice by decantation. The results are shown in Table I.

Table I

Size	Product	Per Cent Wt.	Loss on Ignition	Assays, Per Cent		Per Cent Distribution	
				Al ₂ O ₃	SiO ₂	Al ₂ O ₃	SiO ₂
5	Feed.....	100.00	26.27	51.70	12.38	100.00	100.00
	+65 mesh.....	44.55	29.23	51.47	5.39	44.35	19.40
	Total sand.....	59.01	28.61	51.42	6.09	58.69	29.02
10	Feed.....	100.00	28.01	52.46	12.66	100.00	100.00
	+65 mesh.....	42.26	28.01	53.57	5.37	43.16	41.93
	Total sand.....	55.72	28.48	52.80	5.90	56.20	26.00
15	Feed.....	100.00	25.98	52.06	12.95	100.00	100.00
	+65 mesh.....	44.64	28.66	52.92	6.09	45.37	21.00
	Total sand.....	56.85	28.19	52.42	6.42	57.22	28.18
20	Feed.....	100.00	26.42	52.12	12.27	100.00	100.00
	+65 mesh.....	44.39	29.25	52.95	5.48	45.10	19.83
	Total sand.....	56.40	28.60	52.47	5.80	56.65	26.67
25	Feed.....	100.00	28.40	51.70	12.44	100.00	100.00
	+65 mesh.....	42.68	29.13	52.27	5.73	43.76	19.67
	Total sand.....	57.28	28.52	51.85	6.24	57.44	28.76

It will be noted that in each case from approximately 71 to 74% of the total silica was rejected and the weight recovery of total sands was excellent at from 55 to 59%. These results indicate that preliminary crushing is important only in order that the larger sizes in the aggregate can be reduced sufficiently to pass between the bars of the rotor and stator. Uniformly successful silica rejection appears to have been obtained combined with good recovery regardless of the size of the feed.

EXAMPLE 2

In order to show the effect of excessive grinding without the necessary degree of agitation to produce effective hydration, a number of samples of the same ore were carefully stage-crushed in a wet rod mill to pass a 20 mesh screen; the samples being ground in three stages with the undersize being removed between each stage. In samples 1 and 2, sodium hydroxide was used to maintain a basic medium and with the third sample, CaO was used. The ground ore was diluted to about 15% solids and deslimed by settling and decantation. The results are shown in Table II.

Table II

Sample		Per Cent Wt.	Loss on Ignition	Assays, Per Cent		Per Cent Distribution	
				Al ₂ O ₃	SiO ₂	Al ₂ O ₃	SiO ₂
55	Feed.....	100.00	28.99	51.20	12.55	100.00	100.00
1	Slime.....	55.28	28.22	50.66	16.25	54.91	71.56
	Sand.....	44.32	27.44	51.62	7.98	45.09	28.44
2	Slime.....	62.66	28.93	51.07	15.31	62.50	76.44
	Sand.....	37.34	28.09	51.42	7.92	37.50	23.56
3	Slime.....	62.10	26.50	51.90	15.33	62.95	75.84
	Sand.....	37.90	27.78	50.05	8.00	37.05	24.16

¹ Assay average of many samples. Grinding: 3-5 minute stages with -20 mesh removed after first and second stages. Desliming: Settling and decantation.

EXAMPLE 3

A similar sample of the same ore was crushed to pass a 14 mesh screen. One portion of the minus 14 mesh ore was diluted to about 20% solids and wet screened without further treatment. A second portion was also diluted to 20% solids and subjected to a 5 minute treatment in a Fagregren flotation machine with the air shut off and then deslimed by wet screening. The results which are shown in the following Table

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III, clearly show the increased beneficiation produced by the process of the present invention over that obtainable by crushing and washing alone.

Table III

Time of Agitation		Per Cent Wt.	Loss on Ignition	Assays, Per Cent		Distribution, Per Cent	
				Al ₂ O ₃	SiO ₂	Al ₂ O ₃	SiO ₂
0-----	Feed ¹ -----	100.00	26.99	51.20	12.55	100.00	100.00
0-----	-200 mesh..	42.73	24.86	50.15	19.78	41.86	67.33
	+200 mesh..	57.27	28.57	51.98	7.16	58.14	32.67
5 min....	-200 mesh..	50.87	24.72	49.92	19.99	49.60	81.02
	+200 mesh..	49.13	29.33	52.53	4.85	50.40	18.98

¹ Assay average of many samples.

It should be pointed out that the assays of both

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metallic aluminum. In the shortest period the residual silica content was just within the commercial limitation, whereas in the two longer periods the residual silica content was correspondingly lower. However, the longer periods resulted in excessive loss of alumina and the handling of the material was complicated by the formation of considerable silica gel.

EXAMPLE 5

In order to show the saving in time obtainable by the use of a flotation machine, another portion of the same crushed ore of Example 4 was diluted to approximately 20% solids in water and subjected to a five minute treatment in a Fagregren flotation machine with the air shut off. The material was then wet screened, cuts being made at plus 65 and plus 200 mesh. The results are shown in Table V.

Table V

Time	Product	Per Cent Wt.	Loss on Ignition	Assays, Per Cent			Distribution, Per Cent		
				Al ₂ O ₃	Fe ₂ O ₃	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	SiO ₂
0-----	Feed-----	100.00	26.99	51.20	6.94	12.55	100.00	100.00	100.00
5 Min. in Flotation Machine....	+65 mesh....	37.37	29.72	53.07	10.04	4.58	38.73	54.06	13.64
	+200 (total)---	49.13	29.33	52.53	10.30	4.85	50.40	72.95	18.98

feed and product are expressed in terms of total Al₂O₃ and total SiO₂. Since most of the silica is present as kaolinite, for each unit of SiO₂ discarded there is a necessary loss of 0.85 unit of equivalent alumina. Consequently, the recovery of Al₂O₃, based on available Al₂O₃, is actually much higher than the 50.40 shown in Table III.

EXAMPLE 4

In order to show the effect of varying the period of agitation another sample of the low-grade ore was crushed to about 14 mesh, diluted to about 15% solids with water, and subjected to gentle agitation in a rolling drum without any mixing or grinding element such as rods or balls being used. The crushed ore was divided into several portions. Three portions were agitated for a period of fifty minutes, 19½ hours, and 48 hours respectively. In each case the pulp was wet screened, cuts being made at plus 65 and plus 200. The results are shown in Table IV.

Table IV

Time	Product	Per Cent Wt.	Loss on Ignition	Assays, Per Cent		Distribution, Per Cent	
				Al ₂ O ₃	SiO ₂	Al ₂ O ₃	SiO ₂
0-----	Feed-----	100.00	26.99	51.20	12.55	100.00	100.00
50 min....	+65 mesh....	42.23	29.10	52.69	6.17	43.46	20.77
	+200 (total)---	55.13	28.63	52.42	6.68	56.45	29.34
19½ hours..	+65 mesh....	36.75	29.60	51.75	4.81	37.14	14.08
	+200 (total)---	48.49	29.23	51.45	5.13	48.72	19.82
48 hours....	+65 mesh....	36.11	30.16	51.76	4.44	36.51	12.77
	+200 (total)---	46.14	29.75	51.51	4.77	46.42	17.55

It will be noted from these results that in each case the total plus 200 mesh sands were of commercially acceptable grade for the production of

As will be seen, both the plus 65 and the total plus 200 sands are commercially acceptable for the production of metallic aluminum and are particularly low in silica content. The total plus 200 sands are also commercially suitable from the point of view of total recovery. No gel is formed in this treatment. The shortened time of five minutes practically eliminates the entire soaking period. The Fe₂O₃ content can readily be brought below 7% by tabling without raising the silica above the 6.5% maximum required for abrasive manufacture.

EXAMPLE 6

In order to illustrate the beneficiating possibilities of the agitation treatment, a sample of low-grade Georgia bauxite ore was crushed to pass a ½ inch screen, diluted with water to about 15% solids and agitated in a slowly revolving drum for 92 hours. The pulp was then deslimed by settling and decantation. Desliming was rendered difficult by the presence of considerable quantities of gel formed during the rolling treatment. The results are shown in the following table.

Table VI

	Per Cent Wt.	Loss on Ignition	Assays, Per Cent		Distribution, Per Cent	
			Al ₂ O ₃	SiO ₂	Al ₂ O ₃	SiO ₂
Feed-----	100.00	26.40	55.12	14.68	100.00	100.00
Slime-----	75.96	25.07	53.64	17.52	73.92	90.64
Sand-----	24.04	30.57	59.81	5.72	26.08	9.36

EXAMPLE 7

In order to illustrate the effect of short-time agitation, a number of samples of the same low grade Georgia bauxite ore were crushed to pass a

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½ inch screen and made into a sludge at about 35% solids. These were then agitated for 0, 3, 10 and 20 minutes respectively with a mechanical stirrer, stirring at a rate sufficient to produce a definite boiling action and adding any necessary water to insure ready agitation as the sludge thickened. Desliming was effected by settling and decantation. The results are shown in Table VII.

Table VII

Time		Per Cent Wt.	Loss on Ignition	Assays, Per Cent		Distribution, Per Cent	
				Al ₂ O ₃	SiO ₂	Al ₂ O ₃	SiO ₂
0.....	Feed.....	100.00	26.60	55.04	14.67	100.00	100.00
	Slime.....	10.42	20.23	47.42	28.34	8.98	20.13
	Sand.....	89.58	27.34	55.93	13.08	91.02	79.87
3 min.....	Feed.....	100.00	26.51	54.44	15.27	100.00	100.00
	Slime.....	21.85	20.55	47.80	27.69	19.18	39.63
	Sand.....	78.15	28.18	56.30	11.79	80.82	60.37
10 min.....	Feed.....	100.00	26.59	55.32	14.41	100.00	100.00
	Slime.....	35.29	21.94	49.46	24.87	31.55	60.89
	Sand.....	64.71	29.12	58.52	8.71	68.45	39.11
20 min.....	Feed.....	100.00	26.69	55.46	14.21	100.00	100.00
	Slime.....	41.42	22.49	50.19	23.62	37.49	68.87
	Sand.....	58.58	29.97	59.18	7.55	62.51	31.13

EXAMPLE 8

In order to demonstrate that the agitation did more than merely remove an increased amount of fines, a screen analysis of the sands obtained from the non-agitated sample was made. The results are shown in Table VIII.

Table VIII

Screen Size	Per Cent Wt.	Loss on Ignition	Assays, Per Cent		Distribution, Per Cent	
			Al ₂ O ₃	SiO ₂	Al ₂ O ₃	SiO ₂
+10 mesh.....	57.38	27.25	56.23	12.91	58.82	50.51
-10, +65 mesh..	21.51	27.08	55.59	13.72	21.71	20.12
-65 mesh.....	10.69	28.41	54.98	12.68	10.68	9.24

I claim:

1. A method of beneficiating low grade bauxite ores, which ores comprise bauxite-minerals particles aggregated with an excess of firmly-

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attached hydratable silica-bearing gangue, to produce a high grade bauxite concentrate suitable for the production of metallic aluminum and assaying not more than 7% silica, which comprises: crushing the ore to from about minus ½ inch to plus 14 mesh under such conditions as to produce a minimum of minus 14 bauxite mesh fines; forming the crushed ore particles into an aqueous pulp, whereby the hydratable gangue on the particles surfaces is wetted and transformed to a hydrated water-dispersible form; agitating the aqueous pulp under conditions producing essentially self-attrition only, whereby the hydrated gangue is detached and dispersed immediately hydration is complete without producing excessive size-reduction of the bauxite particles; continuing the agitation and self-attrition in the presence of water until a major portion of the hydratable gangue becomes hydrated and dispersed; and desliming the treated pulp in the presence of water.

2. A process according to claim 1 in which the desliming operation is carried out by hydraulic classification.

3. A process according to claim 1 in which the desliming operation is carried out by washing and screening.

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