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CONCENTRATION OF IRON ORES BY FROTH FLOTATION

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The invention described herein may be manufactured and used by or for the Government of the United States for governmental purposes without the payment to me of any royalty thereon in accordance with the provisions of the act of April 30, 1928 (ch. 460, 45 Stat. L. 467).

This invention relates to the beneficiation of oxidized iron ores and more particularly to the beneficiation of oxidized calcareous iron ores by froth flotation of calcareous diluents from an alkaline pulp of the ore.

Conventional iron-ore beneficiation processes take little or no cognizance of the calcite contained in certain ores, but are concerned primarily with rejection of the maximum amount of insoluble matter possible.

This invention has as an object the development of an improved process for the isolation of calcium-containing minerals from oxidized iron minerals.

A further object is the development of a flotation process for obtaining calcium-containing concentrates of high purity from calcareous oxidized iron ores.

A still further object is the isolation by flotation of the calcium-containing minerals present in certain iron ores, with a minimum loss of iron from the resulting concentrated iron product.

Another object is the isolation by flotation of the calcium-containing minerals from oxidized iron ores while retarding the flotation of the iron oxides and insoluble materials.

Other objects, purposes, and desirable features of the invention will appear hereinafter or will be understood from the subsequent description of its practice.

The invention accordingly comprises a method of isolating the calcareous constituents of various iron ores by employing anionic-collecting agents to float the calcareous material from caustic alkaline iron ore pulps having a pH at least as high as about 9.3, while retarding flotation of the iron oxides with water-soluble silicates. Proper control of pulp pH is of considerable importance. Dextrin, soda ash, lignin sulfonate, or mixtures of these materials in moderation may be used as supplementary reagents in conjunction with the various water-soluble silicates, if desired, but are not obligatory in the practice of this invention.

My experiments show that any of the soluble silicates (ortho-, meta-, or sesqui-silicates) can be used in the practice of this invention upon proper adjustment of reagent quantities. I prefer, however, to use the least expensive form commonly known as water glass.

The soluble silicates are so well-known in industry that any discussion of their nature seems largely unnecessary. However, concisely, soluble silicates are manufactured by fusing finely divided silica (SiO_2) and an alkaline material such as soda ash. The fused product resembles glass but may be dissolved, by special processes, in water. A number of different grades may be produced by varying the proportions of the ingredients, or by special processes which produce specific properties, but the ratio of alkali to silica normally lies between 1:3.2 and 1:3.86. The soluble silicates are very largely marketed as water solutions or as readily soluble hydrated powders.

In the practice of this invention, desliming is neither necessary nor especially desirable, particularly when a maximum rejection of calcareous material is desired. Flotation of deslimed charges may be accomplished without difficulty, but the reagent combination readily enables filming and flotation of slime calcite as well as granular calcite. Froths are compact, heavily mineral-

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ized, and clean readily to yield concentrates of high quality.

Although caustic alkaline pulps with a pH of approximately 10 are preferred in the practice of this invention, acceptable results have been obtained throughout the range of about pH 9.3 to about 12.0. Iron slimes are most effectively retarded at a pH value above 9.5, and concurrently, anionic collector efficiencies are increased above this pH value. In practice, the indicated pH range of operation is of considerable importance. Tests have been made in which visually well-dispersed pulps have been obtained at pH values ranging down to 8.0. Nevertheless, optimum conditions for calcite flotation from iron ores were not established below a pH of 9.3 and only partial flotation of calcite in relatively barren or lightly mineralized froths was obtained. Moderate quantities of alkaline reagents other than caustic, such as other alkali metal hydroxides, ammonium hydroxide, sodium sulfide, sodium carbonate, or mixtures of these materials, may be used to augment the natural alkaline reaction of the silicates in pH adjustment. Reasonable quantities of hydrated lime may also be used as an alkalizer in the separation, although such a use in one sense defeats the purpose of isolating moderately pure calcite for subsequent controlled blending with the final iron products, as the lime activates fine silica to anionic flotation so that a part of the mineral, if present in the ore being treated, reports in the calcite concentrate.

A moderate amount of calcium and magnesium salts may be present in the water used in the process without deleterious effect. Thus, "soft water" is not a prerequisite of the separation.

The anion-active collecting agents suitable for the selective flotation of calcite from iron oxides and silica include the higher fatty acids, exemplified by red oil or oleic acid, purified or crude soaps of these acids, fish-oil soaps, fish-oil fatty acids, paper-mill sulfate soaps, and tall oils. Sulfonated petroleum products also may be used to replace part of the red oil.

The quantities of the various reagents utilized in the practice of this invention are subject to considerable variation, and optimum quantities are best determined by experimentation for any particular ore or product treated. Purity and yield of separated products are reliable guides for reagent adjustment. A large excess of collecting agent, under the conditions of trial, tends to float additional iron minerals in the roughing operation, but the latter are retarded without difficulty in subsequent cleaners. A deficiency of collector results in incomplete flotation of the calcite. Large excesses of soluble silicate tend to retard calcite, whereas a deficiency results in little more than partial collection of the calcite and decrease in selectivity as regards iron oxides. Frothing agents such as the higher alcohols, pine oil, cresylic acid, etc., may be used to advantage in the cleaning operations. A critical study of the results of numerous batch flotation tests indicates that the relatively large optimum quantity of silicate used in batch work may be considerably reduced in continuous operation, as it will be readily apparent to those skilled in the art that the large quantities of calcite reporting in the middlings whenever silicate concentrations are somewhat reduced in batch work in all probability would in part report in the finished concentrates when middlings were retreated by conventional continuous operation flotation methods. However, the "higher than normal" pH must be maintained to obtain continued selectivity.

In describing the results of tests made on various iron ores, for simplicity and convenience, the cleaner tailings or middlings from the two cleaning or refloating operations, being enriched in iron, will be calculated in a "composite iron product" composed of flotation tailings and middlings (cleaner tailings). As stated above, it will be apparent that the grade of the "middlings" and hence the "Fe product" would be improved by recirculation in plant operations.

It will also be noted that the removal of calcite of necessity results in an increase in the insoluble matter content of the ores. In a copending application Serial No. 290,842, filed May 29, 1952, in which I am a joint inventor there is described a two-stage process for se-

lectively removing calcite and silica from oxidized iron ores as individual concentrates.

The invention will be further illustrated, but is not intended to be limited by the following examples of practice.

Example 1

A sample of relatively low grade, highly calcareous limonitic iron ore was obtained from an operating mine in the Longwy area of eastern France. The ore was typical of the area and was largely comprised of oolitic limonite associated with calcite, an iron silicate mineral, and a small amount of quartz. A head analysis gave 32.9 percent Fe, 17.4 percent CaO, and 6.7 percent hydrochloric acid insoluble (hereinafter referred to as "insol.").

In carrying out the flotation process according to this invention, the iron ore or product to be treated is first ground to a suitable size for flotation (if not already of such size) by standard or conventional methods. The fineness of grind may vary from 35 to 200 mesh or finer, depending on the size required for substantially complete liberation of the ferruginous minerals from the diluents or gangue minerals. Although overgrinding is to be avoided, good liberation is essential for a satisfactory flotation separation. On the present ore, grinding to pass 100 mesh yielded acceptable results.

A 250-gram portion of minus 20 mesh rolls crushed ore was ground with 400 cc. water to pass 100 mesh in a laboratory rod mill containing 25 pounds of 1/2-inch steel rods. The ground charge was then transferred to a small mechanical flotation cell of standard design, and sufficient tap water added to give a pulp containing about 25 percent solids.

Flotation of the calcareous constituent of the ore was then achieved from a pulp having a pH of 10.0 using commercial red oil (impure oleic acid) as the collector, and "N" Brand sodium silicate (a commercial sodium silicate having a Na₂O-SiO₂ ratio of 1:3.22 and containing approximately 63 percent water; silicate reagent charges shown in these examples are based on the water solution "as received") as the silica and iron oxide depressant. The reagent charge used expressed in the con-

tional sodium silicate to retard the remaining iron oxides. The pine oil improved the froth condition of the second cleaner.

The final calcite rejects, the combined iron concentrates (cleaner tailings) from the cleaning steps, and the rougher iron concentrates were dried, weighed, and assayed.

The results of the test were as follows:

Product	Wt., percent	Assay, percent			Distribution, percent		
		Fe	CaO	Insol.	Fe	CaO	Insol.
Calcite product.....	36.3	9.1	44.1	1.8	10.0	92.1	9.8
Fe Concentrates:							
Rougher.....	48.9	47.6	1.3	9.3	70.9	3.7	68.3
Cleaner.....	14.8	42.4	5.0	9.9	19.1	4.2	21.9
Composite.....	63.7	46.4	2.2	9.4	90.0	7.9	90.2
Composite Feed.....	100.0	32.9	17.4	6.7	100.0	100.0	100.0

The calcite fraction isolated accounted for 36.3 percent of the weight of the feed, contained 92.1 percent of the CaO present in the ore, and only 10.0 percent of the Fe and 9.8 percent of the insol. The grade of the iron product was raised from 32.9 percent to 46.4 percent Fe with a 90 percent recovery of the iron values.

These results were about average of those obtained on charges of this calcareous limonite ore ground in various types of mills to pass 65, 100, and 200 mesh, respectively. The calcite was rejected without difficulty in the tests by using 0.3-2.0 pounds per ton of the various anionic collecting agents heretofore mentioned, together with sufficient alkalinizing agents to provide a pH from 9.5 to 11.0.

Example 2

The effect of variations in the quantity of soluble silicate retardant is shown in the following example. Several individual 250-gram charges of the calcareous limonitic French ore were ground to pass 100 mesh in the manner of Example 1. These charges, including slime, were individually subjected to identical flotation conditions (similar to those of Example 1, using 1.12 pounds red oil per ton of ore) other than for variations in the quantity of sodium silicate used as iron and insol retardant and small adjustments in the quantity of caustic, to maintain a constant pulp pH of 10.0. Results are summarized in the following table:

Test	Soluble silicate lb./t. ore	Froth product				Iron product (middlings+tailings)							
		Weight percent	Assay, percent			CaO rec., percent	Weight percent	Assay, percent			Recovery, percent		
			Fe	CaO	Insol.			Fe	CaO	Insol.	Fe	CaO	Insol.
A.....	0.0	1.4	21.4	28.9	3.6	2.2	98.6	32.5	17.1	6.6	99.1	97.7	99.2
B.....	1.0	13.5	9.0	36.3	3.3	36.3	86.5	36.4	12.1	7.4	96.3	63.7	96.7
C.....	2.0	29.9	9.0	44.0	1.8	76.3	70.1	42.0	5.8	8.6	91.6	23.7	91.9
D.....	4.0	29.3	7.8	46.9	1.6	76.1	70.7	42.6	6.1	8.9	92.9	23.9	93.0
E.....	8.0	30.0	6.8	46.8	1.3	80.8	70.0	43.2	4.8	8.9	93.7	19.2	94.1
F.....	12.0	34.7	8.3	45.1	1.6	89.7	65.3	44.7	2.8	9.3	91.1	10.3	91.5
G.....	16.0	28.1	6.9	49.1	1.3	77.0	71.9	42.7	5.7	9.0	94.9	23.0	94.6

ventional terms of pounds of reagent per ton of ore was as follows:

Reagent	Conditioner		Rougher	Cleaner	
	No. 1	No. 2		No. 1	No. 2
Sodium silicate, "N"					
Brand.....	12.0	-----	-----	1.0	-----
Red Oil.....	-----	1.92	-----	-----	0.08
Pine Oil.....	-----	-----	-----	-----	1.2
Time, min.....	2.5	2.5	2.5	1+2	1+2
Pulp, pH.....	10.0	-----	9.5	9.7	9.5

The pulp, including approximately 30 percent by weight of slimed ore finer than 20 microns in size, was conditioned for flotation in two stages. In the first conditioner the sodium silicate established the desired alkalinity and retarded the iron oxides and siliceous material. In the second conditioner the ore was conditioned with the red oil, as indicated. This filmed and prepared the calcareous constituents for flotation. Air was then allowed to enter the cell and resulted in the immediate formation of a compact, heavily mineralized froth of the calcareous materials. The froth was collected for 2.5 minutes whereupon flotation was complete. This rougher froth was cleaned by refloating, as indicated, in the same cell using tap water for makeup, and using a small amount of addi-

It is readily apparent from a study of the table that, although moderately high calcite rejections were obtained when quantities of silicate of 2 pounds and above per ton of ore were used (provided a pulp pH above 9.3 was obtained), optimum results were not obtained until the concentration of reagent reached 8-12 pounds per ton of ore treated. Furthermore, froth characteristics were progressively better as this concentration was increased. Higher quantities (test G) tended to retard the calcite.

Example 3

In the preceding examples of practice, soluble silicates alone were employed to retard the iron oxides during anionic flotation of the calcareous constituents of the ore. I shall now describe the results of flotation tests wherein auxiliary addition agents are employed to supplement the soluble silicates in the practice of my invention. A number of variations, employing smaller concentrations of silicate in conjunction with various supplementary dispersants, such as lignin sulfonates, dextrans, soda ash, etc., were tried. It was found that certain of these reagents could be utilized advantageously to reduce the quantity of silicate required, though uniformly best results from the standpoint of froth characteristics were obtained when the silicate was used alone. In all instances, adjustment of pulp pH to at least 9.3 was a basic requirement. By means of some of the reagent combinations, thoroughly

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dispersed pulps were obtained in the pH range of 8-9, but under the conditions of trial, a satisfactory calcite rejection was not effected.

Employing minus 100-mesh charges of the same ore, as well as the general test procedure used in Example 1, the following composited iron products were obtained by use of auxiliary agents supplementing the iron oxide retarding effect of the soluble silicates. In all instances

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In the following table, it will be seen that in test A, though the pulp was visually well dispersed, only a small weight of material was floated from a pulp having a pH of 9.15. Furthermore, the rougher froth contained 26.6 percent Fe as compared to an average of 19 to 20 percent Fe in similar products obtained in the tests made at a higher pH. It is thus evident that the reagent combination improves selectivity.

Test	Conditioner		Weight, percent calcite product		Fe conc. composite, assay, percent		Percent Fe recovery	Percent CaO rejection
	Reagents	pH	Rougher	Cleaner	Fe	CaO		
A-----	Na ₂ CO ₃ Silicate "N"..... Red Oil.....	0.8 0.5 1.28	9.15	15.5	0.0			
B-----	Silicate "N"..... NaOH..... Red Oil.....	12.0 0.4 1.12						
C-----	Silicate "N"..... NaOH..... Red Oil.....	12.0 4.0 1.12						
D-----	Silicate "N"..... NaOH..... Red Oil.....	12.0 12.0 1.12	11.6	62.5	47.0	46.5	2.4	77.1
E-----	Silicate "N"..... NaOH..... Red Oil.....	12.0 4.0 0.32						
			10.9	49.6	35.9	44.1	4.2	87.5
								84.1

NaOH, as needed, was used to adjust the pulp pH to 30 about 10.0.

Depressant used	Pounds per ton	Assay, percent			Percent Fe recovered	Percent CaO rejected
		Fe	CaO	Insol.		
"N" Brand Sodium Silicate.....	1.0	43.2	4.0	8.8	90.8	84.1
Yellow Corn Dextrin.....	1.0					
"N" Brand Sodium Silicate.....	1.0	44.5	4.2	8.3	89.7	84.6
Lignin Sulfonate.....	1.0					
"N" Brand Sodium Silicate.....	1.0	44.7	3.9	8.6	89.0	85.7
Soda Ash.....	1.0					
Composite, Feed (all tests).....		32.6	17.6	6.3	100.0	100.0

It will be seen that the grade of the products produced in this fashion compare favorably with those obtained in tests utilizing silicate alone as retardant. Best froth characteristics, however, were obtained in the normal "high silicate" tests.

Example 4

The importance of maintenance of a proper pulp pH in the practice of my invention, as previously mentioned, cannot be overemphasized. This factor is of prime importance not only with regard to optimum iron oxide retardation, but also with reference to essentially complete removal of calcite from the pulp. The combination of reagents used in the practice of my invention with pulps within the proper pH range results in both good collector efficiency and high selectivity. There is no sacrifice of selectivity in order to obtain high collector efficiency, as might be expected by those versed in this art. Anionic or soap flotation of minerals from pulps having a pH above 9.5 results in considerably increased collector efficiency. Optimum selectivity with reference to the retardation of iron oxide minerals and flotation of calcite is achieved in accordance with the present invention in the pH range above 9.3-9.5. Below that point, in those instances where flotation can be achieved by means of anionic collecting agents, both iron oxide and calcareous minerals tend to float in a non-selective manner. The foregoing observations are illustrated as follows:

Several 250-gram charges of the limonitic ore of Example 1 were ground through 100 mesh and floated (without being deslimed) in the manner previously described. The feed contained 32.6 percent iron (largely as limonite), 17.6 percent CaO, and 6.3 percent acid insoluble matter. In each test the rougher froth product was "cleaned" or refloats twice to yield a cleaner reject or final calcite product. Similarly, in each test, the two cleaner tailings or middlings were combined by calculation with the rougher tailing or machine discharge to yield a "composite iron concentrate." In continuous operation, of course, the middlings would be recirculated and it may be anticipated that the over-all grade of finished product would be slightly better than is indicated in the present batch work.

Likewise, it will be noted that collector efficiency was low in test A and that none of the calcite carried through the cleaning operation. In the higher pH range, filming efficiency increased progressively (tests B, C, D) until it was possible in test E to reduce the collector to a third the quantity previously used. Relatively little change in the character or grade of the finished product was noted, although in the extremely high pH range (test D) a part of the ferruginous minerals again showed a tendency to film and float. However, this factor is considered of secondary importance as operation probably would best be undertaken in the 9.5 to 11.0 pH range from both an economic and equipment corrosion standpoint.

Example 5

The flotation tests heretofore reported were all made on a typical calcareous hydrated iron oxide or limonite ore. I shall now consider the application of my method of flotation to a typical calcareous iron ore in which the iron values are present in the form of an earthy type of hematite. In the particular ore to be considered at this time, there is also present a considerable amount of acid insoluble matter. As my method of flotation retards this material as well as the iron oxide, the insoluble matter content of the iron product is greater than that of the feed. In the aforementioned copending application, Serial No. 290,842, filed May 29, 1952, in which I am a joint inventor, there is described a process for beneficiating iron ores by froth flotation wherein a two-stage procedure of selectively beneficiating such ores is employed. Complete treatment of ores containing both calcareous and siliceous constituents would require use of a procedure of this nature whenever the two gangue minerals were to be isolated as individual products. I am presently concerned, however, with only the first stage of this selective flotation procedure—namely, the isolation, under controlled conditions, of a major part of the calcite present in the ore. The following example of practice must, therefore, be evaluated only from this standpoint.

A sample of calcareous and siliceous hematite ore, locally known as "Big Seam Red Ore," was obtained from the Birmingham, Alabama, district. The ore was typical of the district and contained hematite associated with a gangue composed predominantly of quartz and calcite. Minor quantities of shale and ferruginous clays also were present. A head analysis gave 36.4 percent Fe, 12.0 percent CaO, and 22.4 percent hydrochloric acid insoluble.

A 250-gram charge of the calcareous iron ore was ground to pass 100 mesh in the manner described in Example 1. The ground charge, including slime, was transferred to a small mechanical flotation cell of standard design and sufficient tap water added to give a pulp for flotation containing about 22 percent solids. Flotation of the calcite from the slime-bearing pulp was effected by the following

reagents expressed in conventional terms of pounds per ton of flotation feed:

Reagent	Conditioner		Rougher	Cleaner		
	No. 1	No. 2	1	No. 1	No. 2	No. 3
NaOH.....	0.5	-----	-----	-----	0.2	0.2
Na ₂ CO ₃	1.0	-----	-----	-----	-----	-----
Sodium Silicate "N".....	4.0	-----	-----	-----	0.1	0.1
Red Oil.....	-----	1.12	-----	-----	-----	-----
Time, minutes.....	2.5	2.5	3	3	3	3
Pulp pH.....	10.1	-----	9.6	9.4	9.9	9.8

The slime-bearing pulp was conditioned with caustic, soda ash, to replace part of the silicate, and sodium silicate "N" (a 40 percent aqueous solution, added on an as received basis). Red oil was then added as filming agent, and the pulp again conditioned briefly as indicated. The rougher froth was cleaned by refloating in the same cell, using tap water for dilution together with additional caustic soda and silicate. The froth (calcite product) and composited Fe product (middlings plus tailings) were dried, weighed, and analyzed.

The results of the test are as follows:

Product	Weight, percent	Assay, percent			Distribution, percent		
		Fe	CaO	Insol.	Fe	CaO	Insol.
Calcite concentrate.....	27.2	15.2	38.0	6.6	11.4	86.0	8.0
Composite Fe product.....	72.8	44.3	2.3	28.3	88.6	14.0	92.0
Composite feed.....	100.0	36.4	12.0	22.4	100.0	100.0	100.0

The flotation process resulted in the isolation of 86 percent of the calcite with a loss of only 11.4 percent of the Fe. The composite Fe product, though still containing siliceous material, was nevertheless increased in grade from 36 to 44.3 percent Fe. For illustration purposes, subsequent treatment by the method of my co-pending application, to reject silica, produced an over-all 85 percent Fe recovery in a "final iron product" having an assay of 54.7 percent Fe, 2.3 percent CaO, and 12.5 percent insol.

The results of the previously described flotation tests are typical of those obtained on a variety of calcareous ores, using various silicates and combinations of silicates with other iron oxide depressants as retardants while floating calcite from iron ore pulps made alkaline to a pH above 9.3 by means of caustic soda, sodium sulfide, or by the natural alkalinity derived from a relatively high concentration of silicate. Oleic acid, or red oil, is the preferred collecting agent or calcite promoter, in the practice of my invention, but sodium oleate, tall oil, sulfate soap, petroleum sulfonates, fish oil fatty acids, or similar anionic collecting agents or combinations thereof, have also been successfully used for this purpose.

The practice of my invention affords a means of positively controlling, in the case of calcareous iron ores, the quantity of calcite remaining in the ore from which a part of the insoluble matter has been, or is to be, removed. In the event an essentially "self-fluxing" product is desired from the beneficiation processes, positive means of assuring the proper acid-base relationships are provided. The high-grade calcite isolated by my process may readily be recombined with the iron product, once siliceous gangue has been removed by any of several possible methods.

The process also affords a positive rejection of the maximum quantity of calcite that might be desired in the event the ores or products are transported for considerable distances to the blast furnaces. Transportation charges in some instances are sufficiently great to warrant isolation and rejection of the material at the mine and to supply fluxing material from calcite or dolomite deposits more immediately adjacent to the furnaces.

Since many widely differing embodiments of the invention will occur to one skilled in the art, the invention is not limited to the specific details illustrated and described, and various changes may be made therein without departing from the spirit and scope thereof.

What is claimed is:

1. A process for selectively isolating the calcareous constituents of calcareous iron ores comprising subjecting an

alkaline pulp of the iron ore having a pH at least as high as about 9.3 to froth flotation with an anionic-collecting agent selected from the class consisting of higher fatty acids, resin acids, mixtures of fatty and resin acids, and soaps thereof, and retarding flotation of the iron oxides with water-soluble silicates in an amount providing an iron oxide depressing action equivalent to that of from 2 to 12 pounds of sodium silicate solution of 63 per cent water content per ton of ore.

2. A process for beneficiating calcareous iron ores which comprises conditioning an aqueous pulp of the comminuted ore with a quantity of alkali metal silicate sufficient to establish a pulp pH at least as alkaline as pH 9.3, adding to the alkaline pulp an anion-active collecting agent selected from the class consisting of higher fatty acids, resin acids, and mixtures of fatty and resin acids, and soaps thereof, and then subjecting said pulp to agitation and aeration whereby calcareous diluents are floated and beneficiated iron ore is depressed and recovered.

3. A process for beneficiating calcareous iron ore comprising forming an aqueous pulp of the comminuted ore, adding alkali metal silicate and a dispersing agent to the pulp in an amount providing an iron oxide depressing action equivalent to that of from 2 to 12 pounds of sodium silicate solution of 63 per cent water content per ton of ore, adjusting the pH of the pulp to at least as high as about pH 9.3, adding an anion-active collecting agent selected from the class consisting of higher fatty acids, resin acids, mixtures of fatty and resin acids, and soaps thereof, to the alkaline pulp, and then subjecting said pulp to agitation and aeration, floating the calcareous material from the iron oxides and insolubles, and separately recovering beneficiated iron oxide and material high in CaO content.

4. A process for beneficiating calcareous iron ore comprising forming an alkaline pulp of the comminuted ore having a pH in the range of from about 9.3 to about 11.0, including a quantity of alkali-metal silicate in said alkaline pulp in an amount providing an iron oxide depressing action equivalent to that of from 2 to 12 pounds of sodium silicate solution of 63 per cent water content per ton of ore, adding an active anion-collecting agent selected from the class consisting of higher fatty acids, resin acids, mixtures of fatty and resin acids, and soaps thereof, to the alkaline pulp, and then subjecting said pulp to agitation and aeration, floating off the calcareous material from the depressed iron oxides, and recovering the beneficiated iron ore.

5. A process for beneficiating calcareous iron ore comprising forming a pulp of the comminuted ore, adding to the pulp a quantity of alkaline materials including alkali-metal silicates in an amount providing an iron oxide depressing action equivalent to that of from 2 to 12 pounds of sodium silicate solution of 63 per cent water content per ton of ore, to raise the pH of the pulp to at least about 9.3, adding an anion-active collecting agent to the alkaline pulp, and then subjecting said pulp to agitation and aeration whereby calcareous diluents are floated and beneficiated iron ore is depressed, and recovering the beneficiated iron ore.

6. A process for beneficiating calcareous iron ore comprising forming an aqueous pulp of the comminuted ore, adding sodium silicate solution containing about 63 per cent water to the pulp in an amount of about 8 to 12 pounds of the reagent solution per ton of ore, adjusting the alkalinity of the pulp to a pH of about 10.0, conditioning the pulp for flotation by the addition of an anionic collecting agent selected from the class consisting of higher fatty acids, resin acids, mixtures of fatty and resin acids, and soaps thereof, subjecting the conditioned pulp to agitation and aeration whereby calcareous material is floated and beneficiated iron ore is depressed, and separately recovering the beneficiated iron oxide and calcareous material.

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