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## CONCENTRATING VANADIUM ORES BY ATTRITION FOLLOWED BY FROTH FLOTATION

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This invention relates to a method of concentrating ores and more particularly to a method of concentrating vanadium ores which may or may not contain uranium and radium, in order to produce a vanadium concentrate for final recovery of the metals by a roasting process.

The ores are of the nature of sandstones containing chloritic minerals in which vanadium minerals are associated as inclusions. The most common chloritic mineral in vanadium ores is glauconite. With the glauconite or chloritic minerals other vanadium minerals may be present such as carnotite or roscoelite.

Among the objects of the invention are:

1. To recover slime like minerals containing vanadium and associated metals;

2. To remove by the application of the flotation process undesirable lime bearing minerals such as calcite;

3. To remove and reject as a waste product siliceous and quartz minerals by froth flotation;

4. To recover vanadium minerals included in chloritic minerals as a nonfloating residue from the above flotation operation;

5. To improve the effectiveness of concentration and metal recovery and to make possible commercialization of leaner or hitherto commercially unworkable ores (simultaneously decreasing the cost of recovered values) by decreasing the tonnage of ore hauled to and treated by the subsequent roasting process for final recovery of the metals.

In carrying out the present invention on a vanadium ore containing quartz, calcite and chloritic minerals, the ore is crushed and ground, the grinding preferably being to an extent so as to grind the ore down to approximately the original quartz grain size. This grinding releases a very substantial amount of the metals (vanadium and uranium and associated radium) in and with the colloidal clay minerals of the ore. Organic complexes are also released. The ground ore then is preferably deslimed in water and the slime recovered but this desliming may be omitted in certain cases. The residual sands from the desliming operation are given a wet scrubbing by agitating them with water in any suitable machine, as for example, a flotation machine. In the event that the desliming step just mentioned is omitted, the ground ore is subjected to the wet scrubbing operation. In either case, in carrying out this wet scrubbing operation the scrubbing is continued only until the quartz grains are reasonably freed of adhering minerals but the calcite and chloritic mineral grains remain relatively intact. This wet scrubbing results in an almost total and complete release of the colloidal complexes and the metals. The ore is then deslimed and the slime containing a considerable portion of the metal values is recovered.

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The deslimed sands are then subjected to froth flotation in which the calcite is first recovered as a froth concentrate by using a fatty material as a flotation reagent. Suitable fatty acid flotation reagents for recovering calcite are sodium oleate, naphthenic acid or linoleic acid or the salts of these acids, tall oil or its alkali or ammonium combinations. This flotation yields a calcite product in which some of the metals concentrate and which may be separately rescrubbed or recleaned to recover additional metals before rejecting as a waste product.

After the flotation and removal of the calcite, the cleaned quartz may be floated as a reject froth product by the use of lead salts. Generally there is sufficient of the fatty acid reagents remaining from the calcite product to give good promotion of the quartz with lead salts. However, additional fatty acid reagents may be added if necessary. Suitable lead salts are lead nitrate, lead chloride or lead acetate. Other water soluble lead salts may also be employed. Ordinarily the quartz flotation product is a low grade waste product but additional cleaning, scrubbing and desliming may be used if necessary or profitable before rejecting it.

The nonfloating residue of the quartz flotation is a concentrate of chloritic minerals containing sufficient included metals to be acceptable as a metal concentrate suitable for roasting.

The following are examples which illustrate my invention:

### Example I

Stock pile ore composed of various commercial ores from seven different areas in Colorado, Utah, New Mexico and Arizona was used. The ore was ground to pass a 65 mesh screen and deslimed in water. The slime recovered is designated S–1, in Tables I and II. After desliming, the residual sands were agitated in a flotation machine at an approximate dilution of one part sand to one part water for 45 minutes. After this scrubbing agitation the pulp was diluted with water and again deslimed. This second slime is designated S–2 in the tables.

The residual sands from the second desliming was returned to the flotation machine, diluted to a consistency of four parts water to one part sands and subjected to froth flotation using as reagents

0.30 lbs. naphthenic acid and 2.35 lbs. sodium oleate per ton of original head ore. There was removed, as a froth product, a calcite reject material designated F–1.

Following the calcite flotation, crude lead nitrate equivalent to 1.0 lbs. per ton original head ore was added to the flotation pulp and the flotation continued. There was removed a rougher froth product which was recleaned by flotation yielding a reject quartz product designated F–2 and a cleaner tailing marked CT to be later returned to the process. The residue or nonfloating product remaining from the above rougher quartz froth is a chloritic mineral product designated T.

The metallurgical distributions of the products with analyses of this example were as follows:

*Table I*

| Product | Mark | Percent Weight | Percent $V_2O_5$ | Percent $U_3O_8$ | Percent $CaCO_3$ |
|---|---|---|---|---|---|
| First Slime | S–1 | 9.43 | 5.48 | 0.35 | 8.90 |
| Second Slime | S–2 | 14.52 | 7.20 | 0.42 | 7.25 |
| Calcite Froth | F–1 | 4.01 | .51 | 0.05 | 69.30 |
| Reject Quartz Froth | F–2 | 69.59 | .24 | 0.02 | 0.49 |
| Flot. Residue | T | 1.18 | 4.04 | 0.04 | 1.26 |
| Quartz cleaner tail | CT | 1.27 | 1.86 | 0.04 | .85 |
| | | 100.00 | | | |

The percentage distributions in the products were as follows:

*Table II*

| Product | Percent Weight | | Percent $V_2O_5$ | | Percent $CaCO_3$ | |
|---|---|---|---|---|---|---|
| | Rejected | Recovered | Rejected | Recovered | Rejected | Recovered |
| S–1 | | 9.43 | | 28.37 | | 16.65 |
| S–2 | | 14.52 | | 57.36 | | 20.90 |
| F–1 | 4.01 | | 1.10 | | 55.16 | |
| F–2 | 69.59 | | 9.22 | | 6.77 | |
| T | | 1.18 | | 2.63 | | 0.30 |
| CT [1] | | .32 | | .66 | | .11 |
| CT | .95 | | 0.66 | | .11 | |
| Totals | 74.55 | 25.45 | 10.98 | 89.02 | 62.04 | 37.96 |

[1] Since CT is a return-to-process-product, it is assumed that one half of the $V_2O_5$ and $CaCO_3$ and three fourths the weight will be finally lost or rejected. The balance will be recovered.

The final over-all separation was:

*Table III*

| Product | Per Cent Wt. | Analyses | | Recovery | |
|---|---|---|---|---|---|
| | | Per Cent $V_2O_5$ | Per Cent $CaCO_3$ | $V_2O_5$ | $CaCO_3$ |
| Concentrate | 25.45 | 6.37 | 7.51 | 89.02 | 37.96 |
| Waste tail | 74.55 | .27 | 4.19 | | |
| Total | 100.00 | | | | |
| Head Ore | 100.00 | 1.83 | 5.04 | | |

Ratio of concentrate 3.9.
Ratio $CaCO_3$ to $V_2O_5$ in concentrate 1.18.
Ratio $CaCO_3$ to $V_2O_5$ in head ore 2.76.

EXAMPLE II

A low grade ore considered noncommercial in the present state of the art, and containing higher calcite content to a degree which would render the roasting process highly difficult and costly, was treated identically in all respects as in Example 1.

This yielded a final over-all separation as follows:

*Table IV*

| Product | Per Cent Wt. | Per Cent $V_2O_5$ | Per Cent $CaCO_3$ | Recovery | |
|---|---|---|---|---|---|
| | | | | $V_2O_5$ | $CaCO_3$ |
| Concentrate | 15.21 | 6.51 | 6.00 | 89.96 | 16.38 |
| Waste tails | 84.79 | .13 | 5.50 | | |
| | 100.00 | | | | |
| Head ore | 100.00 | 1.10 | 5.58 | | |

Ratio of concentration 6.6.
Ratio $CaCO_3$ to $V_2O_5$ in concentrate 0.92.
Ratio $CaCO_3$ to $V_2O_5$ in head ore 5.07.

It is thus very significant that low grade, high calcite noncommercial ores which exist in great tonnages may be treated by the process of this invention yielding a satisfactory concentrate low in calcite and quite suitable for final recovery of the metals by the roasting process.

It will be understood that the process as described in connection with Examples I and II is for concentrating ores containing objectionable amounts of both quartz and calcite, and accordingly in that process both quartz and calcite are separated from the chloritic minerals. In some ores where the calcite content is low in amount the calcite flotation step may be omitted. Furthermore as previously indicated the desliming step of Example I following grinding of the ore and preceding wet scrubbing of the ore may be omitted.

The invention is not limited to the preferred procedure but may be otherwise embodied or practiced within the scope of the following claims.

I claim:

1. In a method of concentrating vanadium-bearing sandstone ores containing more siliceous material than $V_2O_5$, the steps comprising wet scrubbing the ground ore until the quartz grains are reasonably free of adhering minerals but the chloritic mineral grains remain relatively intact, desliming and recovering the slime, subjecting the residual sands to froth flotation, employing a lead salt and a member of the group consisting of higher fatty acids, naphthenic acid and soaps derived from such acids and recovering quartz as a flotation product.

2. In a method of concentrating vanadium-bearing sandstone ores containing more siliceous material than $V_2O_5$, the steps comprising wet scrubbing the ground ore until the quartz grains are reasonably free of adhering minerals but the chloritic mineral grains remain relatively intact, desliming and recovering the slime, subjecting the residual sands to froth flotation with a lead salt and a member of the group consisting of higher fatty acids, naphthenic acid and soaps derived from such acids, removing quartz as a flotation product, and recovering the non-floating residue of the quartz flotation.

3. In a method of concentrating vanadium-bearing sandstone ores containing more siliceous material than $V_2O_5$, the steps comprising wet scrubbing the ground ore until the quartz grains are reasonably free of adhering minerals but the calcite and chloritic mineral grains remain relatively intact, desliming and recovering the slime, subjecting the residual sands from said desliming to froth flotation, employing a member of the group consisting of higher fatty acids, naphthenic acid and soaps derived from such acids, remov-

ing calcite as a froth product in such amount that the non-floating residue has a ratio $CaCO_3:V_2O_5$ not over 3, adding a lead salt to the flotation pulp and removing quartz as a flotation product, and recovering the non-floating residue of the quartz flotation.

4. In a method of concentrating vanadium-bearing sandstone ores containing more siliceous material than $V_2O_5$, and having a ratio $CaCO_3:V_2O_5$ of the order of at least 5, the steps comprising desliming the ground ore and recovering the slime, wet scrubbing the residual sands until the quartz grains are reasonably free of adhering minerals but the calcite and chloritic mineral grains remain relatively intact, desliming and recovering the slime, subjecting the residual sands from said second desliming to froth flotation, employing a member of the group consisting of higher fatty acids, naphthenic acid and soaps derived from such acids, removing calcite as a froth product in such amount that the non-floating residue has a ratio $CaCO_3:V_2O_5$ not over 3, adding a lead salt to the flotation pulp and removing quartz as a flotation product, and recovering the non-floating residue of the quartz flotation.

5. In a method of concentrating vanadium-bearing sandstone ores containing more siliceous material than $V_2O_5$, and having a ratio $CaCO_3:V_2O_5$ of the order of at least 5, the steps comprising wet scrubbing the ground ore until the quartz grains are reasonably free of adhering



minerals but the calcite and chloritic mineral grains remain relatively intact, desliming and recovering the slime, subjecting the residual sands from said desliming to froth flotation, employing a member of the group consisting of higher fatty acids, naphthenic acid and soaps derived from such acids, removing calcite as a froth product in such amount that the non-floating residue has a ratio $CaCO_3:V_2O_5$ not over 3, adding a lead salt and a member of said group to the flotation pulp and removing quartz as a flotation product, said flotation product containing not over 0.30% $V_2O_5$ and recovering the non-floating residue of the quartz flotation.

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