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METHODS FOR THE ENRICHMENT OF BAUXITE ULTRAFINES

The material studied consists of extremely small (10-20 nm diameter) particles of iron oxide adhering to the surface of submicron sized particles of gibbsite, boehmite, kaolin and anatase: which can be removed by mild reductive leaching. The minerals constitute Weipa bauxite ultrafines and it is shown that the iron oxide content may be reduced from 5.1% to 1.7% without disrupting the other minerals' lattices. The limit of 1.7% is equal to that obtained by extensive leaching with hydrochloric acid. Further discrimination between the cleaned minerals is possible using dispersion, sedimentation, centrifugation and flocculation techniques. For example, an anatase enriched product or a gibbsite rich, iron and boehmite depleted product may be obtained. Relevant separation mechanisms are discussed.

INTRODUCTION

The Weipa bauxite deposit is situated on the Cape York Peninsula in Northern Queensland, the most northerly part of Australia.
The bauxite consists principally of gibbsite and boehmite. Associated minerals include kaolinite, quartz, hematite, goethite and anatase. The bauxite deposits were formed as the result of lateritic weathering of tertiary sediments [1]. The particles in the bauxite ore have a distinct trimodal size distribution. The largest proportion of material consists of pisolites which generally fall in the size range 1-20 mm. This material is used to feed the Bayer alumina process. A large proportion of the deposits fall in the size range 0.1-1.0 mm and are generally formed by the breakdown of the pisolites. There is also a considerable proportion of material of size less than 2 μm, referred to in this study as the ultrafines. This material constitutes approximately 10% of the total Weipa ore. In this size range the constituent minerals are reported to occur as discrete particles rather than as composites whereas in the larger size fractions quartz is the only liberated mineral [2].

The production of monomineralic particles of boehmite, gibbsite, kaolinite, etc. at sizes less than 2 μm by fine grinding or chemical precipitation is

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prohibitively expensive. Hence the Weipa ultrafine material is a highly prospective source of such finely divided material, for potential use in the production of ceramics and as fillers.

However, the presence of hematite and anatase can lead to a decreased rupture modulus in the formation of ceramics or to undesirable colour if the ultrafine material is used as a filler.

The primary objective of this research programme was to remove hematite and associated iron minerals from the bauxite ultrafines in order to produce a material suitable for use as a fire retardant filler or as a feed material for ceramic manufacture. A secondary objective was to determine whether or not selective separation could be achieved between the residual minerals left in the iron depleted ultrafines.

EXPERIMENTAL

Reagents.
High purity water ($\kappa < 0.5 \times 10^{-6}\Omega^{-1}cm^{-1}$ $\gamma = 72.8$ mNm^{-1} at 25°C) and Analar grade reagents were used unless otherwise stated. Experiments were performed at 25°C.

Feed Material: Dispersion and Composition

The feed material for the production of the ultrafines was the Weipa bauxite beneficiation plant tailings. This material consists of the ultrafines together with a large proportion of broken pisolitic material. The material was presented as a slurry which naturally coagulated and sedimented at pH7.

The material was dispersed by raising the pH to 11 with sodium hydroxide whilst stirring the suspension at high speed with a paddle stirrer in a baffled beaker, followed by further dispersion with an ultrasonic probe. At pH 11, all of the mineral surfaces were negatively charged [3] and the ultrafines remained in suspension. After dispersion, the slurry was transferred to a settling column where the coarse material was allowed to settle out for 100 hours under the action of gravity. The suspended material constituted the ultrafine fraction at 3 wt% solids. 55% by weight of the raw feed reports to the overflow whilst 45% is present in the underflow. The ultrafines were analysed by x-ray fluorescence and wet chemical methods [Comalco Research Laboratories, Melbourne] to determine the total oxides content and loss on ignition (LOI). From these analyses an indicative mineralogical analysis was calculated assuming that all of the SiO_2 was present in kaolin, all of the Fe_2O_3 was present as hematite and all of the TiO_2 was present as anatase. The relative proportions of gibbsite and boehmite were calculated from the LOI after accounting for the H_2O content of the kaolin and the Al_2O_3 content. Typical chemical and mineralogical compositions for raw feed and gravity separation products etc. are given in Table 1. It is significant to note that quartz is present in the raw feed absent from the overflow and is concentrated in the underflow. The iron oxide content is unchanged throughout whilst there is some concentration of anatase in the underflow. Although X-ray diffraction (XRD) is inappropriate for the accurate quantitative estimation of the minerals present, the presence of the minerals in Table 1 and their relative proportions was certainly confirmed by XRD.

Electron Microscopy and Surface Spectroscopy

The ultrafines were examined using Transmission Electron Microscopy, Scanning Electron Microscopy, Electron Diffraction Spectroscopy and X-ray Photoelectron Spectroscopy.

Particle Size Determination.
The particle size distribution of the ultrafines was determined by photon correlation spectroscopy using a Malvern Instruments Autosizer IIc.

Electrophoretic Mobility Measurements.
Electrophoretic mobilities were determined by a combination of photon correlation spectroscopy and microelectrophoresis using a Malvern Instruments Zetasizer IIc. Standard procedures were adopted [4].

Flocculation and Coagulation
Flocculation and coagulation experiments were performed in a standard 0.25 metre high settling column, enabling the settled and suspended material to be separated and assayed.
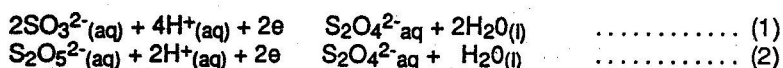
TABLE 1.

Name of Analysis : - Weipa - Feed

CHEMICAL ANALYSIS	PERCENTAGE		
	WEIPA FEED	WEIPA OVERFLOW	WEIPA UNDERFLOW
Total Alumina	54.30	56.30	52.00
Total Silica	13.90	12.00	16.30
Total Quartz	3.20	0.00	6.90
Total Reactive Silica	10.70	12.00	9.40
Total Iron Oxide	5.10	5.10	5.10
Total Titanium Oxide	2.90	2.50	3.40
Loss on Ignition	23.30	23.80	22.70
Total Assay	99.50	99.70	99.50
MINERAL EQUIVALENTS			
Gibbsite	50.89	50.65	50.93
Boehmite	13.69	14.89	12.30
Kaolin	23.78	26.67	20.89
Quartz	3.20	0.00	6.90
Hematite	5.10	5.10	5.10
Anatase	2.90	2.50	3.40
Other loss on ignition	0.30	0.30	0.30
Mineral Assay Total	99.86	100.10	99.81

Leaching

Leaching experiments were performed inside a sealed reaction vessel (as at Figure 1) into which probes for the measurement of pH and E_h were inserted. Combined glass pH and platinum Eh electrodes were used for all pH and E_h measurements.

The leaching experiments also were performed using concentrated hydrochloric acid and sodium dithionite in separate experiments as leachants. A circuit was also devised[Figure 1] whereby slurry could be pumped through an electrochemical cell in which dithionite could be generated in situ by the electrolysis of sodium sulphite or sodium metabisulphite[5]. The electrolysis reactions are:

$$2SO_3^{2-}{}_{(aq)} + 4H^+{}_{(aq)} + 2e \quad S_2O_4^{2-}{}_{aq} + 2H_2O_{(l)} \quad \dots\dots\dots\dots (1)$$
$$S_2O_5^{2-}{}_{(aq)} + 2H^+{}_{(aq)} + 2e \quad S_2O_4^{2-}{}_{aq} + H_2O_{(l)} \quad \dots\dots\dots\dots (2)$$

This reaction takes place at the cathode using direct current. Oxidation and reduction zones were isolated from each other using a porous ceramic membrane. Alternating current may also be used in which case it was observed that the reduction reaction may be switched from one electrode to the other. In addition, the kinetics of leaching of the Weipa ultrafines were studied as a function of initial pH in the presence of sodium dithionite. Samples of pulp were withdrawn with a syringe at various intervals and filtered through a 0.22μm Millipore filter. Soluble iron was determined by Atomic Absorption Spectroscopy using standard procedures.

RESULTS AND DISCUSSION

Borland and McGlade (1985) examined the Weipa ultrafine fraction with transmission electron microscopy TEM and electron diffraction (ED) and observed three types of particles, viz.
  . Equi-axied, roughly hexagonal plates with typical dimensions of 100-200nm.
  . Lath-shaped particles of more variable dimensions but typically <50nm wide and 100-400nm long.
  . Very small equi-axed particles, 10-20nm in diameter.
The particles were identified by their electron diffraction patterns viz:

  . the particles were invariably identified as kaolinite.
  . these particles gave poorly defined ED patterns which were attributed to either goethite or boehmite. This is possibly indicative of iron substitutions for lattice aluminium.
  . all of the small particles gave ED patterns identified as goethite.

All minerals were present as discrete monomineralic particles. Further studies by Smart and Turner (1987) involved the examination of the fines by scanning electron microscopy (SEM), TEM and EDS. These studies revealed the following information:-
  . the fines initially show Fe widely dispersed as very small particles down to 10nm, adhering to the gibbsite and boehmite particles;
  . it is not possible to clearly separate Fe- containing particles from the particles of the matrix;
  . the small particles of all types give poor diffraction patterns consistent with very defective crystal forms;

Effectiveness of Dispersion
In order to disperse the coagulated ultrafine material, the pulp conditions need to be adjusted so that all materials have the same surface charge. There are two ways in which dispersion can readily be achieved:-

. addition of acid or base so that all minerals are of the same surface charge
. addition of a strongly adsorbing reagent which coats the mineral surfaces with charged functional groups which lead to electrostatic and/or steric repulsion.

The widely variable, literature values for points of zero charge and isoelectric points [3,6,7] for gibbsite (3.8 - 10.5), boehmite (6.5 - 9.7) kaolinite (3 - 7.6), hematite (6.2 - 9.5) and anatase (4.7 - 6.0), suggest that by raising the pulp to a high pH (>10.5), all minerals should be negatively charged and remain in suspension due to repulsive electrostatic forces. Alternatively, an adsorbing charged dispersant which specifically adsorbs at the mineral-water interface, giving the minerals a negative or positive surface charge, could be used. The simplest method was addition of NaOH to raise the pH to ~11, when all of the oxide surfaces are negatively charged and the ultrafines remained in suspension. Other inorganic and organic dispersants were also tested. These included sodium hexametaphosphate (Calgon), sodium silicate, sodium silico-fluoride and various sodium and ammonium polyacrylates (e.g. Spersol 100XE, Catoleum 7811, Catoleum CD806, Dispex N40, Dispex A40). The effectiveness of each dispersant was gauged by measurement of the average particle size of the suspended pulp together with electrophoretic mobility determinations. If the pulp was dispersed with Calgon, sodium silicate, polyacrylates etc., the particle size of the material was found to be greater than that found for pulps produced simply by raising the pH to ~11.0 with NaOH. There was no advantage in increasing the pH above about pH 11.5. Beyond pH 11.5 increased coagulation occurred, due to compression of the double layer. Pulps to which dispersants were added were generally quite alkaline due to hydrolysis of the dispersing agent (pH ~ 8-10).

It is difficult to ascertain whether dispersion was due to adsorption of the anion on the mineral surface or to the effect of increased pH, or both. It was also observed that the use of dispersants would result in the surfaces being indiscriminantly coated with dispersant, so that all minerals in the system would be similarly coated. Further reagents could then only be selectively adsorbed on to a particular mineral with some difficulty. The pH 11 dispersion route with NaOH was found to be the most effective (i.e. smallest particle size, most stable dispersion) and least expensive. Particles with a mean diameter of circa 220nm and a range from 118 to 550nm were produced from the raw feed. Electrophoretic mobilities ranged from - 2.7 to -4.0 (μm.cm.V^{-1}.s^{-1})

Fine Particle Separation Behaviour
Attempts to selectively separate the iron oxide from the dispersed ultrafine particles by selective flocculation, shear flocculation and flotation (column, oil or carrier) were all unsatisfactory due to the strong adhesion between the iron oxide contaminant and the other minerals. The presence of Moire fringes in the transmission electron micrographs is indicative of crystal intergrowth between the iron oxide and the host mineral phase.
Selective coagulation is similar to selective flocculation in that aggregation is achieved through inorganic electrolytes rather than polymers. Selective coagulation has been used to separate anatase from clays[8]. Electrolyte is used (potential determining ions or indifferent ions) to change the surface potential or charge of the suspended particles. Even though the minerals

have the same surface potential[9], the rate of coagulation is dependent on the size of the particles and the magnitude of their respective surface potentials[8] so that selective coagulation can be brought about by producing differences in the coagulation rates of each mineral. If the differences in rates of coagulation are of sufficient magnitude one mineral may separate out leaving the others in suspension over a specific period of time.

Preliminary observations demonstrated that if the ultrafines were dispersed at pH 11.2 and if the pH was slowly decreased to circa 10.5, a light coloured sediment formed whilst the remaining suspension was correspondingly darker. This process occurred over twenty-four hours under the influence of gravity. A quantitative experiment was carried out to determine mass balances for all elements in the ultrafines in a separation process incorporating one stage of concentrate cleaning. the feed for this experiment was the Ultrafines overflow (Table 1) and the results are reported in Table 2. The iron content in the underflow is 4.60%, compared with 5.10% in the feed (Table 1), with a marked increase in whiteness of the settled material. There is no significant change in the aluminium bearing mineral content, however there is a very noticeable change in the TiO_2 levels. The titanium mineral selectivity is not due simply to a gravity effect but rather to a selective coagulation process, as can be seen from a comparison of the data inTable 1 with those in Table 2. No further improvement in selectivity was achieved in the presence of inorganic and organic dispersants.

## TABLE 2.

Name of Analysis : - Weipa + NaOH pH 11.2 - 10.5

MINERAL EQUIVALENT	UNDERFLOW	OVERFLOW
Gibbsite	51.28	50.96
Boehmite	11.06	15.91
Kaolin	27.78	26.22
Quartz	0.00	0.00
Hematite	4.60	5.30
Anatase	5.00	1.40
Other Loss on Ignition	0.30	0.30
Mineral Assay Total	100.02	100.09

Leaching

Hot hydrochloric acid leaching reduced the iron content of the ultrafines to 1.9 wt % (Table 3), dissolving substantial quantities of boehmite, gibbsite and kaolin in the process. Recalculation assuming iron oxide was the only mineral dissolves indicates the iron content is 1.7%. This result suggested that the remaining iron was incorporated into the gibbsite, boehmite or kaolin as inclusions of iron minerals or as iron substituting for aluminium in the gibbsite or boehmite lattices, in agreement with earlier electron microscopy determinations. The figure of 1.7% represents an effective lower limit for the ultrafines unless some discrimination between the "cleaned" ultrafine minerals can be made.

The leaching of iron oxides can be readily accomplished using solutions of sodium dithionite at mildly acid pH values [10,11].

The reaction for hematite leaching is:
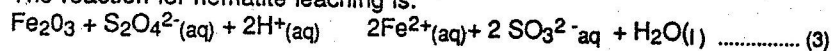
$$Fe_2O_3 + S_2O_4^{2-}{}_{(aq)} + 2H^+{}_{(aq)} \quad 2Fe^{2+}{}_{(aq)} + 2 SO_3^{2-}{}_{aq} + H_2O_{(l)} \quad \text{...............} \quad (3)$$

The kinetics of leaching of the Weipa ultrafines were studied as a function of initial pH in the presence of sodium dithionite. The number of moles of sodium dithionite used was 20% greater than that required to theoretically reduce the iron oxide content of the feed from 5.1% to 1.7%. At a pulp density of 1 wt %, this should, in theory produce an iron concentration in solution of 4.3×10^{-3}M. Samples of pulp were withdrawn with a syringe at various intervals and filtered through a 0.22μm Millipore filter. Soluble iron was determined by Atomic Absorption spectroscopy. The variation of soluble iron with time is given in Figure 2.

TABLE 3.

Name of Analysis : - Overflow after HCl Leaching

MINERAL EQUIVALENTS	PERCENTAGE
Gibbsite	35.23
Boehmite	21.03
Kaolin	38.22
Quartz	0.00
Hematite	1.90
Anatase	3.50
Other Loss on Ignition	0.30
Mineral Assay Total	100.17

The salient features are that:

. the rate of Fe removal is dependent on pH, increasing with decreasing pH. Both the initial rate and the "plateau" shown in Figure 2 increase with decreasing pH.

. two forms of iron oxide are evidently present, the first of which leaches rapidly (hence the "plateau"), whilst the second is far more resistant to leaching. The easily leached form of iron is amorphous iron, whilst the resistant form is hematite. The existence of these phases has been previously discussed. The complete leaching of hematite eventually means that iron oxide levels are reduced to 1.7%.

This technique was effective in removing iron, leading to grades (1.7% iron) and recoveries (≥95%) after prolonged leaching of 24 hours or greater at E_h values of about -200mV and pH 3-6. In practice the process would be bedevilled by

. high operating costs - sodium dithionite is relatively expensive.

. decomposition of dithionite to sulphur in acidic media [12], an event which would be undesirable for potential product uses.

. the need for $Fe^{2+}{}_{(aq)}$ removal.

An electrochemical technique was therefore devised (Figure 1) which enabled dithionite to be electrolytically generated in situ from either sulphite

or metabisulphite (equations 1,2). The advantage with this process is that the dithionite can be both controlled and regenerated. Furthermore elemental sulphur could not be detected as a decomposition product under the experimental conditions.

Representative experimental conditions and results obtained for electrochemical leaching are shown in Table 4. Excellent grades and recoveries were obtained for both AC and DC currents.

The behaviour during electrochemical leaching is conveniently described by the following illustrative experiment (Figure 3).
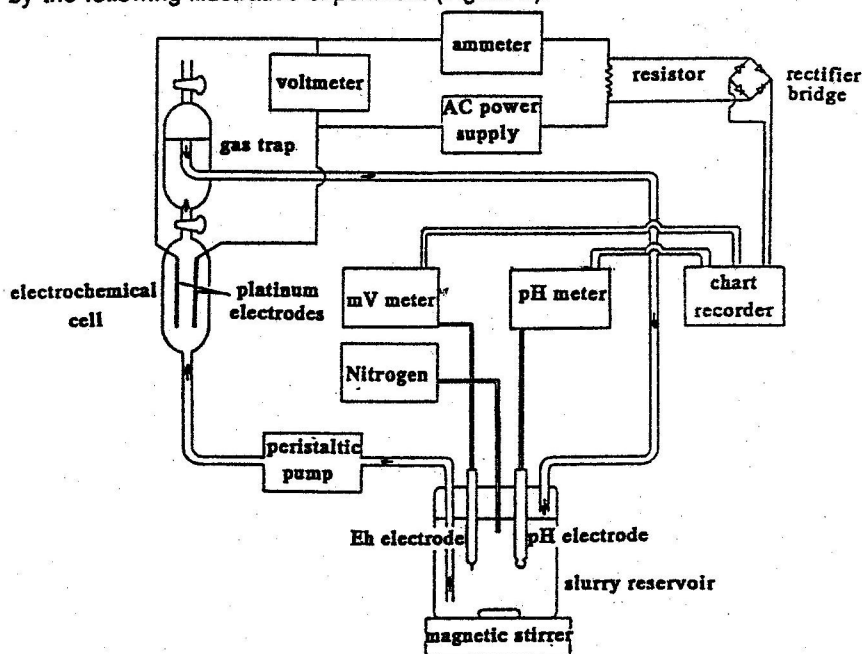
FIGURE 1. Schematic diagram of the electrochemical technique for reductive leaching of bauxite ultrafines

Three clear regions may be identified. In region 1, the Eh decreases to a steady plateau as $S_2O_4^{2-}$ is generated from HSO_3^-. There is a concomitant decrease in pH. Dry solid was injected at the commencement of region II. The current was switched off. Both Eh and pH increase as $S_2O_4^{2-}$ is consumed and iron oxide is reduced and plateau as the concentration of $S_2O_4^{2-}$ approaches zero. The current was turned on at the commencement of region III. The Eh decreases as $S_2O_4^{2-}$ is regenerated, whilst the pH rises due to the consumption of H^+ during iron oxide reducti on. The rate of hematite reduction is, however, less than the rate of $S_2O_4^{2-}$ formation, as shown by the opposing trends in Eh and pH.

This electrolytic leaching technique requires further optimization (e.g. to improve current efficiency) but even at this stage is potentially cost competitive. $Fe^{2+}_{(aq)}$ removal is required as in the case of "chemical" dithionite leaching and could possibly be achieved in practice by passage of the supernatent through an ion exchange column. The leaching experiments described above have succinctly demonstrated that iron oxide

may be removed from the Weipa ultrafines to a lower limit of circa 1.7%. This limit is equivalent to that achieved by extensive leaching with concentrated hydrochloric acid.

The mineral surfaces, cleaned of contaminating iron oxide, may well be amenable to further selective separation. Dried, leached ultrafines obtained from the leaching experiments described above were used in further separation tests.
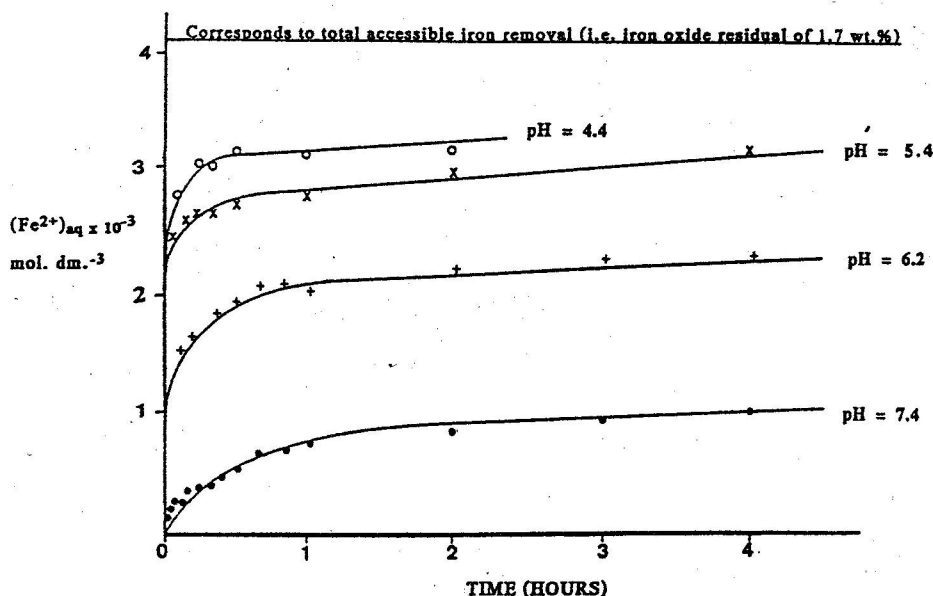

FIGURE 2. Kinetics of leaching of iron oxide as a function of pH.

TABLE 4.

Results of electrochemical Leaching using alternating and direct current.

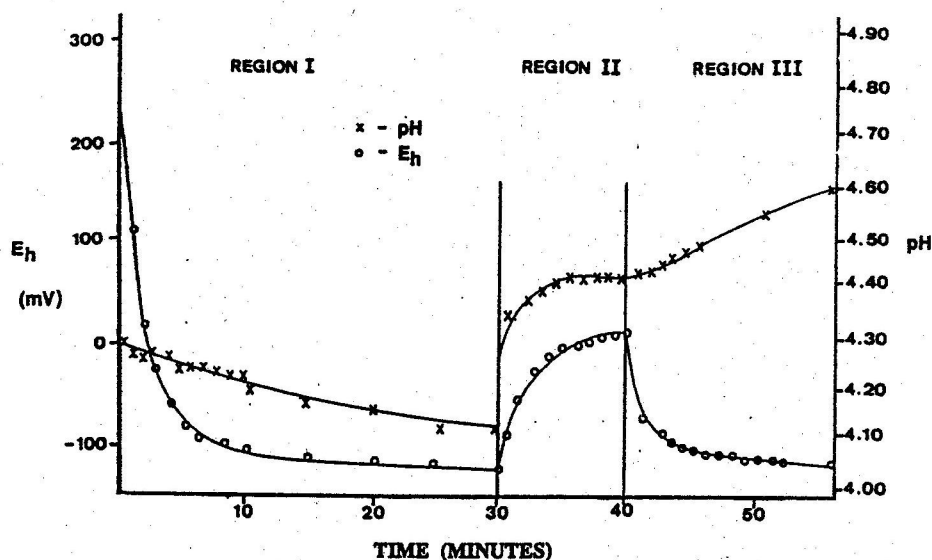|	Al_2O_3%	Fe_2O_3	SiO_2	TiO_2	L.O.I.	Weight loss on leaching %
Direct Current	57.9	1.7	12.4	2.5	25.0	4.0
Alternating Current	58.0	1.7	12.5	2.5	25.0	5.0

FIGURE 3. Eh and pH behaviour during electrochemical leaching

Characterization of Leached Ultrafines.

X-ray photoelectron spectroscopy (XPS) and secondary ion mass spectroscopy (SIMS) revealed that the surface of the leached ultrafines was depleted in iron compared to the unleached material. The particle size distribution and electrophoretic mobilities of these leached ultrafines were determined and compared to the unleached material. The optimum conditions for dispersion of the leached material were shifted to pH 10 in the presence of sodium silicate (at 2 kg tonne^{-1} of solid), compared with pH 11.2 for the unleached material. In both cases the same particle size distribution (average diameter 220 nm) and electrophoretic mobility (μm.cm.V^{-1}.s^{-1}) were determined, within experimental error.

Sedimentation and Selective Flocculation of Leached Ultrafines.

Leached ultrafines were dispersed at pH 10.0 in the presence of sodium silicate. Sedimentation was performed over several days. Concentrates were obtained after one and four days sedimentation. The data in Table 5 illustrate that if 17.5% of the total mass is removed after four days sedimentation, some 45.8% of the total titanium dioxide is removed with very little change in the iron content.

sedimentation, some 45.8% of the total titanium dioxide is removed with very little change in the iron content.

The overflow from this test was used in further attempts to induce selective flocculation of leached ultrafines. A variety of flocculants were used, two of the most effective of which were Magnafloc A-2137 and A-2100. Analysis of the tails and concentrates are given in Tables 6 and 7. Discrimination between gibbsite and boehmite is clearly evident with a distinct change in the ratio between these two minerals in the concentrate and the tail, whilst there is little change in the other minerals except that anatase is depleted in the concentrate.

TABLE 5.
Chemical Analysis of Products Obtained After Dispersion With Sodium Silicate and Sedimentation at pH 10.0.

SAMPLE	L.O.I. %	Al_2O_3 %	Fe_2O_3 %	SiO_2 %	TiO_2 %	Weight %
Concentrate 1 (1 day of sed.) (Underflow 1)	24.2	53.3	1.48	12.4	7.97	6.6
Concentrate 2 (4 days of sed.) (Underflow 2)	23.4	52.5	1.25	15.7	6.74	10.9
Overflow	23.4	58.0	1.73	14.0	1.81	82.5
Feed (Calculated)	23.5	57.1	1.66	14.0	2.75	100.0

TABLE 6.

Name of Analysis : - Selective flocculation using Magnafloc A-2137 (l kg/ton solid).

MINERAL EQUIVALENTS	PERCENTAGE	
	FLOCCULATED SEDIMENT	OVERFLOW
Gibbsite	37.00	50.79
Boehmite	25.94	15.20
Kaolin	33.56	29.56
Quartz	0.00	0.00
Hematite	2.13	1.54
Anatase	1.16	2.09
Other Loss on Ignition	0.30	0.30
Mineral Assay Total	100.09	99.47

TABLE 7

Selective Flocculation using Magnafloc A-2100 (l kg/ton solid).

MINERAL EQUIVALENTS	PERCENTAGE	
	FLOCCULATED SEDIMENT	OVERFLOW
Gibbsite	38.29	49.72
Boehmite	25.17	15.72
Kaolin	33.33	30.22
Quartz	0.00	0.00
Hematite	2.16	1.64
Anatase	0.93	1.95
Other Loss on Ignition	0.30	0.30
Mineral Assay Total	100.19	99.54
RECOVERY	23.5	76.5

Mineral Correlations

From the results of numerous chemical analyses, performed on leached ultrafines dispersed in the pH range 7 to 11 in the presence of various dispersants, and flocculants, significant mineral correlations are evident. In Figure 4, the percentage of iron oxide shows a strong, positive correlation with boehmite content and a negative correlation with gibbsite and kaolinite. Representative points only are shown for clarity.

The key to obtaining iron oxide levels less than the 1.7% benchmark figure would appear to lie in discriminating between boehmite and the other minerals. It is likely that the iron in these leached ultrafines is locked up to a significant extent in the boehmite lattice, either as small inclusions or in Fe substituting for Al. Iron oxide can be reduced to about 1.2% if boehmite is reduced to about 8% or below, correlating with an Al_2O_3 analysis of 52% or greater.

The results shown in Figure 4 are of paramount importance, for they indicate that with the application of colloid chemical techniques subsequent to electrochemical reductive leaching, it is impossible to reduce the iron oxide level to below 1.0%. The proportion of boehmite in the product can be shifted from 8% to 30%, the gibbsite from 55% to 38% whilst the kaolin content remains relatively constant around 30%.
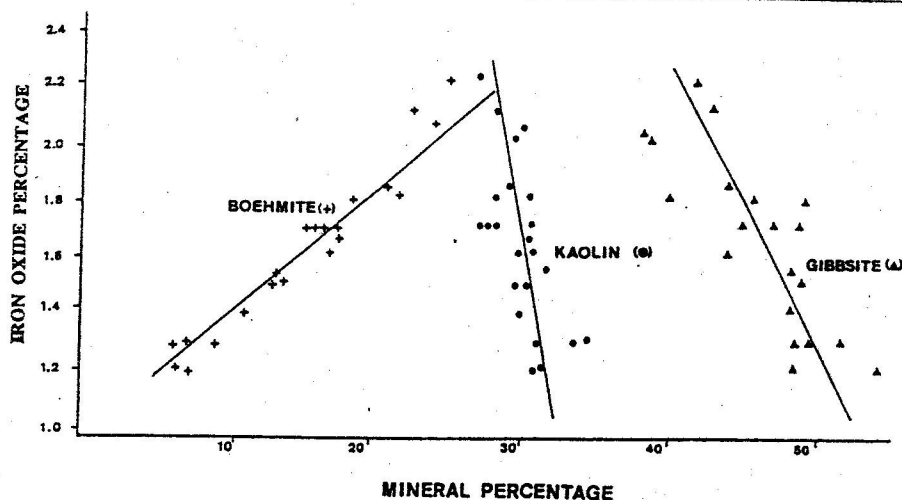
FIGURE 4.   Correlation between mineral type and
iron oxide content

SUMMARY

It has been clearly demonstrated that the iron oxide content of Weipa
ultrafines can be reduced from 5.1% to 1.7% by use of either a chemical or
an electrochemical reductive leaching process. The other minerals' lattices
are not disrupted by electrochemical reductive leaching. Selective
coagulation, by comparison, can reduce the iron content by only about 0.5%,
(from 5.1% to 4.6%). Following iron removal by reductive leaching, the
ultrafines are more receptive to colloid chemical methods of fine particle
separation. Discrimination between the major mineral fractions in these
leached ultrafines can be achieved through dispersion, sedimentation,
centrifugation and flocculation techniques. For example an anatase
enriched product or a gibbsite enriched, iron and boehmite depleted product
can be obtained. We remark, however, that the evidence indicates that it is
impossible to reduce iron oxide levels below 1.0% for the leached ultrafines
without disrupting the major mineral lattices. The evidence indicates that the
electrochemical reductive leaching process is the most efficient process,
possessing both technical and economic potential. Further work on
fundamental aspects of the colloid stability of the ultrafines is in progress and
will be reported in a future paper.

ACKNOWLEDGEMENT

REFERENCES

1.   GRUB, P.L.C., Mineralium Deposita, 6 265 (1985).
2.   LOUGHNAN, F.C. and BAYLISS, P. American Minealogist 46 209
          (1961)

3. PARKS, G., Chem. Reviews (1965) V. 65 177
4. HUNTER, R.J., 'Zeta Potential in Colloid Science' 1981 Academic
    Press
5. CHAO, M.S., J. Electrochem Soc. Vol 133 No. 5 May 1986 p 954
6. STUMM, W., and MORGAN J. 'Aquatic Chemistry' 2nd Ed. 1981
    John Wiley & Sons Inc.
7. JAMES, R., and PARKS G. (Ed. E. Matijevic) 'Surface and Colloid
    Science' Vol. 12 1982 p.119.
8. PUGH, R. and KITCHENER J., J. Colloid and Interface Science
    V.35 No. 4 1971,
9. PUGH, R. J. Colloid and Polymer Science V.252 p. 400 (1974).
10. HILL, B.F., 'The Weipa Kaolin Project' The Aus. I.M.M. Sydney Branch
    Project Development Symposium October 1986.
11. GARRELS, R. and CHRIST, C. 'Solutions, Minerals and Equilibria'
    1965 Harper & Row, John Weatherhill.
12. COTTON, F. and WILKINSON, G., 'Advanced Inorganic Chemistry'
    John Wiley & Sons, 1962.

METODY WZBOGACANIA MUŁOW BOKSYTOWYCH

Badany materiał zawiera niezwykle małe (10-20 nm srednicy) czasteczki tlenku żelaza przylegajace do powierzchni submikronowych czastek gibsytu, bemitu, kaolinu i anatazu, które mogą byc usunięte drogą łagodnego redukujacego ługowania. Wykazano, ze zawartość tlenku żelaza w mułach boksytowych z Waipa można zmniejszyc z 5.1% do 1.7% bez zniszczenia sieci krystalicznych wymienionych minerałów. Osiagnięta granica 1.7% odpowiada wartości otrzymanej przez ekstensywne ługowanie kwasem solnym. Pozwala to na dalsze zróznicowanie własności oczyszczonych minerałów i umożliwia zastosowanie technik dyspersji, sedymentacji, wirowania i flokulacji. Przykładowo, można otrzymać produkty bogate w anataz, jak rownież produkty wzbogacone w gibsyt o małej zawartości żelaza i bemitu. Przeprowadzono dyskusje nad mechanizmem rozdziału.

СОДЕРЖАНИЕ

К.Куйс, Дж.Ральстон, Р.Смарт, С.Собера й, Р.Вуд, 1989. Методы обогащения бокситовых шламов. Физикохимические вопросы обогащения, 21; 23-36.

Исследованный материал содержит необыкновенно мелкие 10-20 нм диаметра частицы окиси железа, прилегающие к поверхности субмикронных частиц гиббсита, бемита, каолина и анатаза, которые можно удалить путем мягкого восстанавливающего выщелачивания. Показано, что содержание окиси железа в бокситовых шламах из района Ваипа можно снизить с 5,1% до 1,7% без уничтожения кристаллических сетей упомянутых минералов. Достигнутая граница 1,7% соответствует значению, полученному путем интенсивного выщелачивания соляной кислотой. Это позволяет дальше усилять особенности очищенных минералов и позволяет применять техники дисперсии, седиментации, центрифугирования и флокуляции. Например, можно получить продукты, богатие анатазом, а также продукты, обогащенные гиббситом с малым содержанием железа и бемита. Проведена дискуссия над механизмом раздела.