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(71) Applicant (for all designated States except US): **THE UNIVERSITY OF QUEENSLAND** [AU/AU]; St Lucia, Queensland 4072 (AU).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **DJORDJEVIC, Nenad** [AU/AU]; 10 Olsen Court, Brookfield, Queensland 4069 (AU). **MANLAPIG, Emmanuel** [AU/AU]; 8 Tucker Street, Chapel Hill, Queensland 4069 (AU).

(74) Agent: **PIZZEYS PATENT & TRADE MARK ATTORNEYS**; Level 14, 324 Queen Street, Brisbane, Queensland 4000 (AU).

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(54) Title: METHOD AND APPARATUS FOR SEPARATING CLAY FROM ORE FRAGMENTS

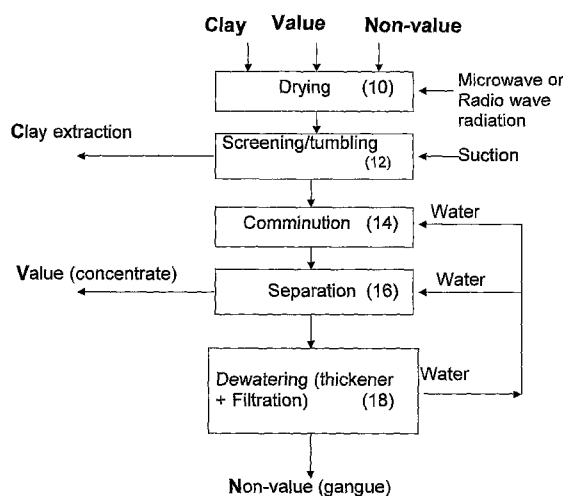


Figure 2. Schematic layout of new mineral processing plant

(57) Abstract: The present invention relates to a method for separating clay from ore fragments comprising clay, including: - drying the ore fragments comprising clay by exposing the ore fragments to radiation having a frequency in the microwave to radio wave spectrum; - separating the dried clay from the ore fragments; - adding water to the ore fragments; and - separating an ore concentrate from gangue in one or more processing steps. The present invention also relates to an apparatus for separating clay from ore fragments comprising clay.

METHOD AND APPARATUS FOR SEPARATING CLAY FROM ORE FRAGMENTS

Field of the Invention

5 The present invention relates to a method for separating clay from ore fragments. The present invention also relates to an apparatus for separating clay from ore fragments.

Background

10 It should be understood that any discussion of the background art throughout the specification should in no way be considered as an admission that such background art is prior art, nor that such background art is widely known or forms part of the common general knowledge in the field.

 Water has now become a scarce commodity especially in remote areas
15 where treatment of ores is conducted. Water is used in the mineral and mining industry and is typically used in processing circuits where comminution, classification and separation of the ores occur.

 Used water is typically recovered through dewatering by thickening
20 filtering, screening and tailings dewatering. Typically, agglomerating agents are added during these processes.

 Ores which contain significant amounts of gangue clays are usually
25 difficult to dewater once they are treated in a mineral processing plant due to the presence of fine sized clays. Once the water has been added to the ore (such as during comminution), it is difficult to separate the water from the fine sized clays.

 Mineral processing plants that treat these ores typically utilise large
30 amounts of water which results in subsequent problems with water recovery. Whilst use of tailings ponds and the like attempt to address this problem, water recovery for recycling is still difficult. This makes water a scarce commodity, especially in continents with arid conditions such as in Australia, South Africa and South America.

Accordingly, the invention seeks to reduce or ameliorate the above-mentioned disadvantages or problems or, at least, seeks to provide an alternative to the prior art.

5 Definitions

The following part of the specification provides some definitions that may be useful in understanding the description of the present invention. These are intended as general definitions and should in no way limit the scope of the present invention to those terms alone, but are put forth for a better
10 understanding of the following description.

Unless the context requires otherwise or specifically stated to the contrary, integers, steps, or elements of the invention recited herein as singular integers, steps or elements clearly encompass both singular and plural forms of the recited integers, steps or elements.

15 Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated step or element or integer or group of steps or elements or integers, but not the exclusion of any other step or element or integer or group of elements or integers. Thus, in the context of this
20 specification, the term "comprising" is used in an inclusive sense and thus should be understood as meaning "including principally, but not necessarily solely".

Throughout the specification, unless the context clearly indicates otherwise, the term "clay" should be understood to include fine grained
25 materials which may be plastic in nature due to inherent water, and which form suspensions in water, particularly when used in the mineral and mining field, and more specifically in mineral processes and plants. The term "clay" should be understood to include but are not limited to fine grained materials such as phyllosilicates, aluminosilicates, laterites and other fine grained minerals which
30 when used in the mining and mineral field become suspended in water.

Summary of the Invention

According to one aspect, the invention provides a method for separating clay from ore fragments comprising clay, comprising:

- drying the ore fragments comprising clay by exposing the ore fragments to radiation having a frequency in the microwave to radio wave spectrum;
- separating the dried clay from the ore fragments;
- adding water to the ore fragments; and
- separating an ore concentrate from gangue in one or more processing steps.

The step of adding water to the ore fragments may be conducted in a comminution step, separation step or to both a comminution step and a separation step.

The method of the invention may comprise the step of drying the ore fragments by radiation having a frequency in the radio frequency range. The frequency may also be in the range of 3Hz to 300MHz, 3Hz to 200MHz, or 3Hz to 100MHz.

The method of the invention may also comprise the step of drying the ore fragments by radiation having a frequency in the microwave frequency range. The step of drying the ore fragments may be achieved by radiation having a frequency in the range of from 400MHz to 3000MHz.

The method of the invention may comprise the step of separating the dried clay by screening the ore fragments comprising clay, tumbling the ore fragments comprising clay or a combination of screening and tumbling the ore fragments comprising clay.

The step of separating the dried clay may also include the use of suction to remove the dried clay. The dried clay may be removed before the comminution stage.

The step of separating the ore concentrate from gangue further may comprise a dewatering step to separate the gangue from the water. The dewatering step may include the addition of an agent, in a particularly example one or more chemical agents which may be selected from the group consisting of a flocculating agent, a thickening agent, an agglomerating agent and

mixtures thereof. The step of dewatering may further comprise filtration by a suitable filtration element of the water from the gangue.

The method of the invention may also preferably include a step of recycling the water from the dewatering step to the comminution step, separation step or both the comminution step and the separation step. The step of recycling the water may also be directed to other steps in the method as required.

The method of the invention may also be a continuous or batch method.

According to another aspect, the invention provides an apparatus for separating clay from ore fragments comprising clay, comprising:

- a chamber for drying the ore fragments comprising clay by exposing the ore fragments to radiation having a frequency in the microwave to radio wave spectrum;
- a chamber for separating the dried clay from the ore fragments;
- a chamber for comminution of the ore fragments; and
- a chamber for separating an ore concentrate from gangue.

The apparatus of the invention may also comprise a chamber for dewatering. The dewatering chamber may include an agent, in a particular example, one or more chemical agents which may be selected from the group consisting of a flocculating agent, a thickening agent, an agglomerating agent and mixtures thereof. The dewatering chamber may further comprise a filtration element to separate the water from the gangue.

In the apparatus of the invention, the chamber for separating the dried clay from the ore fragments may comprise at least one element for screening the dried clay and ore fragments, tumbling the dried clay and ore fragments or both screening and tumbling the dried clay and ore fragments. In particular, there may be present an element for screening the dried clay and ore fragments, another element for tumbling the dried clay and ore fragments. Further, there may be a unitary element which acts to screen and tumble the dried clay and ore fragments.

The chamber for separating the dried clay may also include a suction element to remove the dried clay. In particular, the unitary element which acts to

screen and tumble the dried clay and ore fragments may also include a suction element.

In a particular example, there may be provided a rotatable tumbler having one or more apertures spaced apart in a longitudinal direction of the tumbler. The rotatable tumbler may have a suction element which acts to separate the dried clay from the ore fragments by a vacuum means connected to the one or more apertures. The vacuum means draws the fine clay through the one or more apertures to a separate chamber whilst the ore fragments travel in a downward direction of the rotatable tumbler for further processing in the apparatus of the invention. The dried clay may thus be removed before the comminution stage.

The apparatus of the invention may also comprise a chamber for drying the ore fragments where the radiation in the chamber has a frequency in the radio frequency range. The radio frequency may be in the range of 3Hz to 300MHz, 3Hz to 200MHz, or 3Hz to 100MHz.

The apparatus of the invention may also comprise a chamber for drying the ore fragments where the radiation in the chamber has a frequency in the microwave frequency range. The microwave frequency range may be from 400MHz to 3000MHz.

The apparatus of the invention may comprise a chamber for comminution of the ore fragments which may comprise added water. The chamber for comminution may include a machine including but not limited to cone crushers, roller crushers, impact crushers, tube mills and roller presses. The tube mills may comprise ball mills, semi-autogenous mills or autogenous mills.

The apparatus of the invention may also comprise a chamber for separating the ore concentrate from gangue which may comprise added water. The chamber may further comprise one or more dewatering agents and a filtering element to separate the gangue from water.

The apparatus of the invention may further comprise an element for recycling water from the dewatering chamber or the chamber for separating the ore concentrate from gangue to the chamber for comminution of the ore fragments.

The ore fragments include but are not limited to bauxite ore, nickel laterite ores and copper ores. However, it will be appreciated that other ores which comprise clay are also within the scope of the invention.

The method and apparatus of the invention are energy efficient methods and apparatus which are thought to rely on the difference in the dielectric loss factor and the average density of clay as compared to typical rock forming minerals. The inventors have identified that the average density of clay is significantly lower than for the corresponding rock forming minerals. The inventors have also identified that the dielectric loss factor of clay is significantly higher than for the corresponding rock forming minerals. This difference in either or both of these physical properties allows for the selective and energy efficient method of microwave or radiowave heating of clay as compared to typical rock forming minerals. Whilst not wishing to be bound by any theory, it is thought that the clay readily forms a dried and cracked form upon exposure to microwave and radio wave radiation since clay has chemically and physically bound H₂O molecules present in its microstructure.

The use of microwave and radiowave radiation provides an energy efficient method of converting clay to a dried and cracked form where it can be more easily separated from ore fragments by physical separation elements and steps.

Brief Description of the Drawings

In order that the invention may be more readily understood and put into practical effect, reference will now be made to the accompanying drawings which illustrate preferred embodiments of the invention only, and wherein:

Figure 1 is a schematic representation of a method of conventional mineral processing plant;

Figure 2 is a schematic representation of a method and apparatus for separating clay from ore fragments using microwave or radio wave radiation in accordance with the invention;

Figure 3 is a graphical representation of a dielectric loss factor and density for clay and typical rock forming minerals;

Figure 4 is an infra-red image of a rock fragment during microwave heating in accordance with the invention;

Figure 5 is a picture of a rock fragment after microwave heating in accordance with the invention;

5 **Figure 6, Figure 7 and Figure 8** are pictures of rock fragments prior to microwave heating; and

Figure 6A, Figure 7A and Figure 8A are pictures of the rock fragments shown in **Figure 6, Figure 7 and Figure 8**, respectively, after microwave heating and tumbling in accordance with the invention.

10 In **Figure 1**, there is shown a schematic diagram of a conventional mineral processing method and apparatus. The term "stage" as used in the description of the invention includes a method step and corresponding apparatus chamber. The method includes treating ore fragments which include ore and clay. The ore comprises a value component (concentrate) and a non-
15 value component (gangue).

In a first comminution stage (1) of the method, fresh water is added in one or more stages to the ore and clays. Typical machines which may be used for comminution include crushers including but not limited to cone crushers, roller crushers, impact crushers, tube mills (e.g. ball mills, semi-autogenous or
20 autogenous mills) and roller presses.

Following the first comminution stage (1), there is provided a separation stage (2) where the value component (concentrate) is separated from the non-value component and in this stage water may be added to assist in the separation process. The separation stage utilises the physical characteristics
25 of clay which is that it is broken down into fine particles which are carried in water. The suspension of fine particles in water allows for the water/clay suspension to be separated from the non-value component (gangue).

A dewatering stage (3) is provided after the separation stage (2). The dewatering stage (3) may include the addition of a thickening or flocculating agent so as to allow for separation of the non-value component (gangue) from
30 the water/clay suspension.

The water/ clay suspension, however, cannot be recycled due to the presence of the fine clays suspended in the water. These fine clays are difficult

to separate from the water/ clay suspension. Some attempted solutions to this problem is that the water/clay suspension is transferred to settling ponds and the like which allows for evaporation of water. This leads to substantial loss of water.

5 In **Figure 2**, there is shown a schematic diagram of a method of removal of clay using microwave or radiowave radiation and apparatus according to the invention. The term "stage" as used in the description of the invention includes a method step and corresponding apparatus chamber.

10 The method comprises a stage (10) of drying the ore fragment comprising clay using radiation in the microwave or radio frequency range. After the drying stage (10), there is provided a screening/tumbling stage (12) where the fine clay particles are extracted. The screening stage (12) may utilise a rotatable tumbler (not shown) having one or more apertures spaced apart in a longitudinal direction of the tumbler. The rotatable tumbler may have a suction
15 element which acts to separate the dried clay from the ore fragments by a vacuum means connected to the one or more apertures. The vacuum means draws the fine clay through the one or more apertures to a separate chamber whilst the ore fragments travel in a downward direction of the rotatable tumbler for further processing in the apparatus and method of the invention. The dried
20 clay is thus removed before a comminution stage (14).

The separated ore fragments are then transferred to a comminution stage (14) where fresh water is added to the ore fragments in one or more stages. Typical machines which may be used for comminution include crushers including but not limited to cone crushers, roller crushers, impact crushers, tube
25 mills (e.g. ball mills, semi-autogenous or autogenous mills) and roller presses. However, other suitable machines for comminution may be used.

The value component (ore concentrate) of the ores fragments is separated from the non-value component (gangue) in a separation stage (16). Water is added in one or more stages in this step of the method. Since the
30 clays have been removed from the ore fragments, recycled water from a dewatering stage (18) (as will be described below) may be used in this stage.

The dewatering stage (18) includes the use of an agent, in a particular example, one or more chemical agents which may be selected from the group

consisting of a flocculating agent, a thickening agent, an agglomerating agent and mixtures thereof. The agent assists in the separation of the water from the gangue. The dewatering stage (18) further comprises a filtration element (not shown) to separate the water from the gangue.

5 The water from the dewatering stage (18) can then be recycled back into the comminution stage (14), the separation stage (16) or both of the comminution stage (14) and the separation stage (16).

 The advantage of using radiation in the microwave or radio frequency range is demonstrated in the graphical representation as shown in **Figure 3**
10 which shows the dielectric loss factor and average density for clay as compared to particular rock forming minerals which are selected from quartz, dolomite, kaolin, mica, calcite, amphibole, chlorite, feldspar and muscovite.

 In a specific example of this invention, the advantage of using radiation in the radio frequency range is that the dielectric loss factor of water rapidly
15 increases at a frequency range less than 100MHz. In an embodiment where radiation is used in the microwave frequency range, drying can be performed using radiation having frequencies from 400MHz to 3000MHz. A specific frequency used may be selected from the group consisting of 433MHz, 915MHz or 2450MHz.

20 As can be seen in **Figure 3**, the dielectric loss factor and the average density of clay as compared to the rock forming minerals is significantly different than for the corresponding minerals. The inventors have identified that the difference in either or both of these properties allows for the selective microwave or radiowave heating of clay as compared to typical rock forming
25 minerals.

 It has also been identified that a practical application of the selective heating of the clay as opposed to the typical rock forming minerals is that since the combination of the dielectric loss factor and average density for clay is significantly different than the typical rock forming minerals, the clay can
30 surprisingly be exposed to microwave and radio wave radiation so as to result in a dried and cracked physical form. The use of microwaves and radio waves is more energy efficient when compared to conventional convection heating methods, eg using hot air, radiation elements, etc.

It is thought that the clay readily forms a dried and cracked form upon exposure to microwave and radiowave radiation since clay has chemically and physically bound H₂O molecules present in its microstructure. The use of microwave and radiowave radiation provides an energy efficient method of converting clay to a dried and cracked form where it can be more easily separated from ore fragments by physical separation elements and steps.

Figure 3 also demonstrate that the dielectric properties of clays are significantly different from the dielectric properties of typical rock forming minerals. Whilst not wishing to be bound by any theory, it is considered that the principal reasons for this are size, compositions of clays forming grains and the presence of chemically and physically bound water in clays. The dielectric loss factor for clays may be in the range of 1.3 to 2.5 at a frequency of 2.45GHz which is more than a magnitude higher than values for the dielectric loss factor of typical rock forming minerals as shown in **Figure 3**. Further, the average density of clay is substantially around 1000kg/m³ which is two to three times lower than density of typical rock forming minerals. These differences indicates the possibility for using microwave or radiowave heating of rock fragments covered with clay, for selective heating of clay as compared to rock forming minerals.

Figure 4 illustrates by way of an infra-red image, the difference in the rate of heat absorption of the clays as opposed to the rock forming minerals such as quartz, kaolin, and other minerals. Figure 4 also demonstrates that the difference in physical properties of the clay as opposed to typical rock forming minerals results in the selective heating of the clay as compared to the rock forming minerals.

Figure 5 illustrates a rock fragment comprising clay after exposure to microwave radiation. It should be noted that this picture illustrates the dried cracked nature of clay after exposure to microwave radiation. As discussed above, it is thought that this is due to the fact that clay has chemically and physically bound water in its microstructure. The use of microwave radiation is thought to remove the bound water to result in dried, cracked clay whilst the ore fragments are largely unchanged in physical form. Figure 5 illustrates that

dielectric loss factor and average density of clays are useful indicators which can be utilised to separate clays from rock forming minerals.

Figure 6, Figure 7 and Figure 8 demonstrate the rock fragments prior to exposure with microwave radiation. **Figure 6A, Figure 7A and Figure 8A** demonstrate the dried cracked nature of the clay after exposure to microwave radiation together with a further treatment of tumbling for a period of time of about 10 seconds. It is noted that these representations illustrate that the clays after being treated by the methods and apparatus of the invention are essentially of a dried and cracked form which results in smaller particle sizes which can be easily separated from the ore fragments by physical separation steps or means.

The advantages of the apparatus and method of the invention may include one or more of the following:

- substantial saving of water in mineral processing plants and methods
- reduction or elimination of the use of tailings ponds
- more energy efficient method of removing clay from ore fragments.

Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. It is to be understood that the invention includes all such variations and modifications. The invention also includes all of the steps, features, compositions and compounds referred to or indicated in this specification, individually or collectively, and any and all combinations or any two or more of said steps or features.

CLAIMS:

1. A method for separating clay from ore fragments comprising clay, including:
 - 5 ▪ drying the ore fragments comprising clay by exposing the ore fragments to radiation having a frequency in the microwave to radio wave spectrum;
 - separating the dried clay from the ore fragments;
 - adding water to the ore fragments; and
 - 10 ▪ separating an ore concentrate from gangue in one or more processing steps.
2. A method according to claim 1; wherein the step of drying the ore fragments is by radiation having a frequency in the radio frequency range.
- 15 3. A method according to claim 1 or 2, wherein the frequency is in the range of less than 100MHz.
- 20 4. A method according to claim 1, wherein the step of drying the ore fragments is by radiation having a frequency in the microwave frequency range.
- 25 5. A method according to claim 4, wherein the step of drying the ore fragments is by radiation having a frequency in the range of from 400MHz to 3000MHz.
- 30 6. A method according to any one of the preceding claims, wherein the step of separating the dried clay is by screening and tumbling the ore fragments comprising clay.
7. A method according to claim 6, wherein the step of separating also includes the use of suction to remove the dried clay.

8. A method according to claim 7, wherein the dried clay is removed before a comminution step.
- 5 9. A method according to any one of the preceding claims, wherein the step of separating the ore concentrate from gangue further comprises a dewatering step to separate the gangue from the water.
- 10 10. A method according to claim 9, wherein the dewatering step includes the addition of an agent selected from the group consisting of a thickening agent, an agglomerating agent and mixtures thereof together with filtration.
- 15 11. A method according to claim 10, wherein the water from the dewatering step is recycled to the comminution step or separation step or a combination thereof.
- 20 12. A method according to any one of the preceding claims, wherein water is added to the ore fragments in a comminution step, separation step or to both the comminution step and the separation step.
- 25 13. An apparatus for separating clay from ore fragments comprising clay, comprising:
- a chamber for drying the ore fragments comprising clay by exposing the ore fragments to radiation having a frequency in the microwave to radio wave spectrum;
 - a chamber for separating the dried clay from the ore fragments;
 - a chamber for comminution of the ore fragments; and
 - a chamber for separating an ore concentrate from gangue.
- 30 14. An apparatus according to claim 13, wherein the chamber for separating the dried clay from the ore fragments comprises one or more elements for screening and tumbling the dried clay and ore fragments.

15. An apparatus according to claim 13 or 14, wherein the frequency in the radio frequency range.
- 5 16. An apparatus according to claim 13, 14 or 15, wherein the radio frequency is in the range of less than 100MHz.
17. An apparatus according to any one of claims 13 to 16, wherein the frequency is in the microwave frequency range.
- 10 18. An apparatus according to claim 17, wherein the chamber for drying the ore fragments uses radiation having a microwave frequency in a range of from 400MHz to 3000MHz.
- 15 19. An apparatus according to any one of claims 13 to 18, wherein water is added to the chamber for comminution of the ore fragments.
- 20 20. An apparatus according to claim 19, wherein the chamber for separating the ore concentrate from gangue further comprises one or more dewatering agents and a filtering element to separate the gangue from water.
- 25 21. An apparatus according to claim 20, wherein the apparatus further comprises an element for recycling water from the chamber for separating the ore concentrate from gangue to the chamber for comminution of the ore fragments.

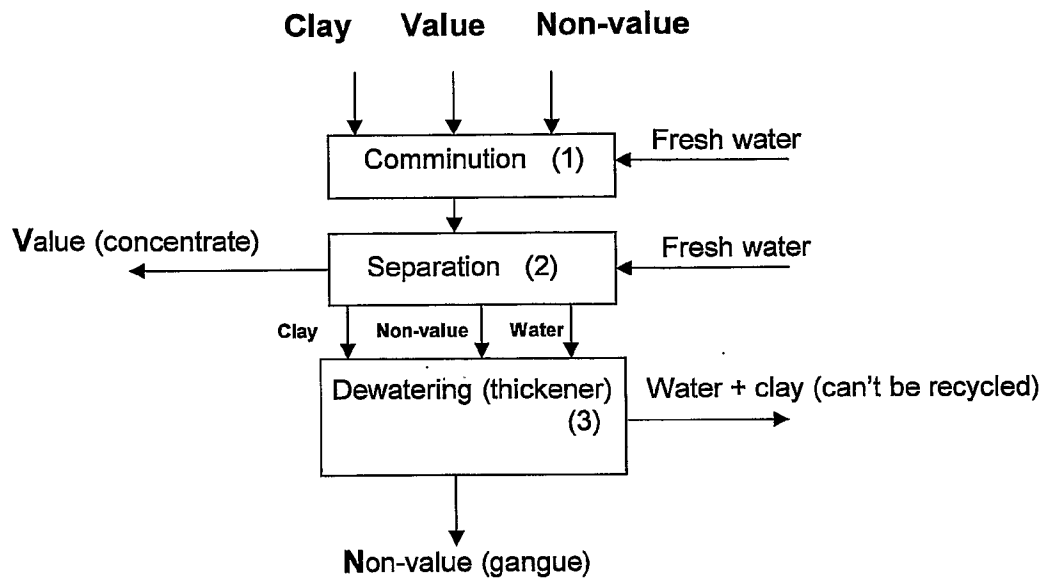


Figure 1. Schematic layout of conventional mineral processing plant

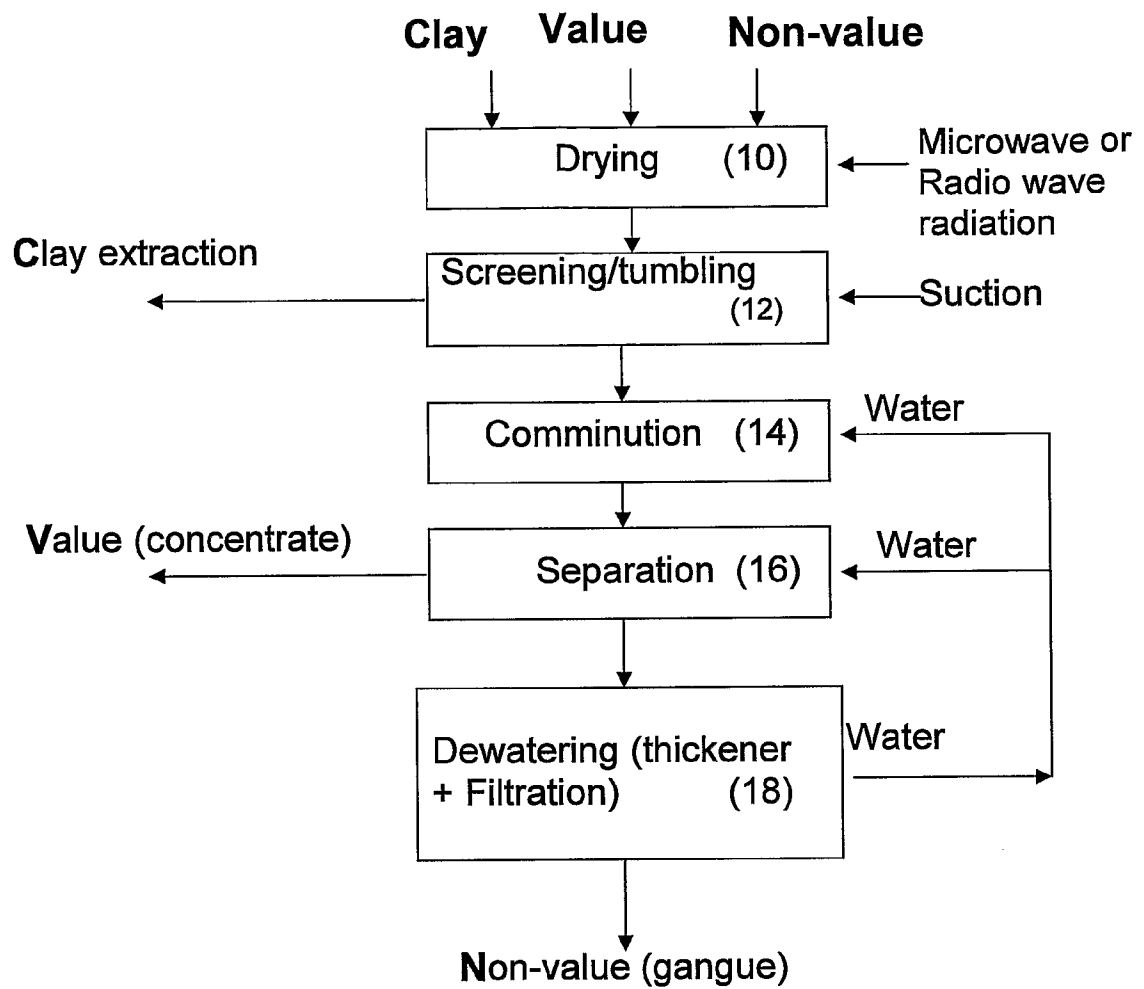


Figure 2. Schematic layout of new mineral processing plant

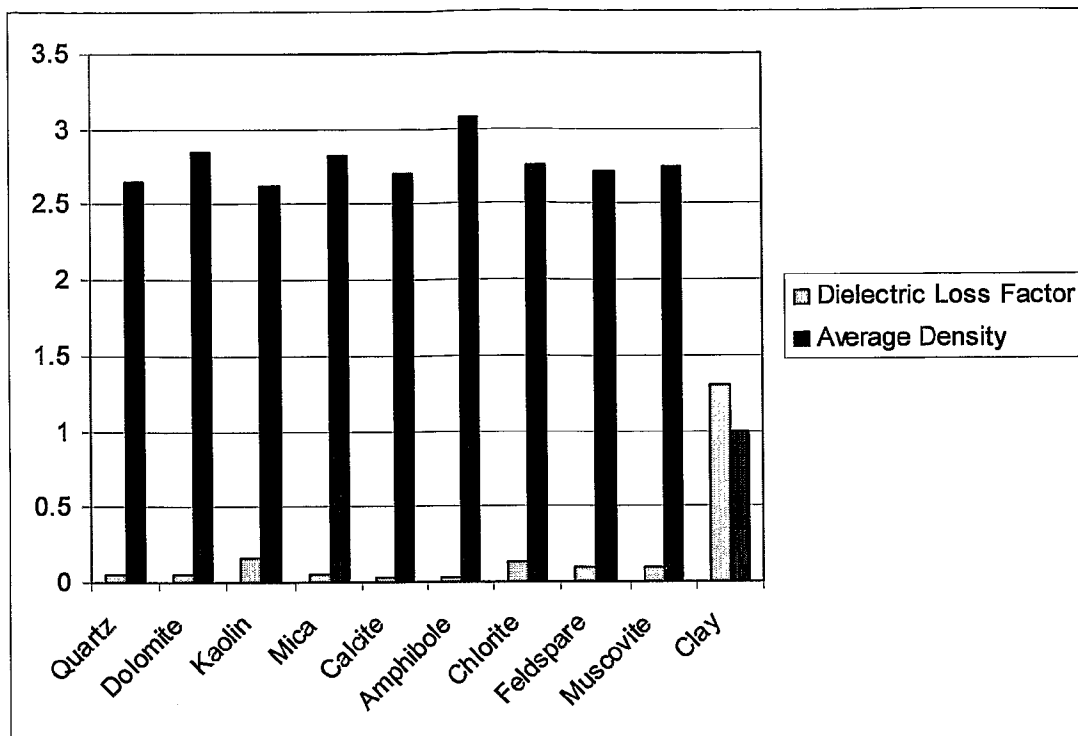


Figure 3. Dielectric loss factor and density for clay and typical rock forming minerals.

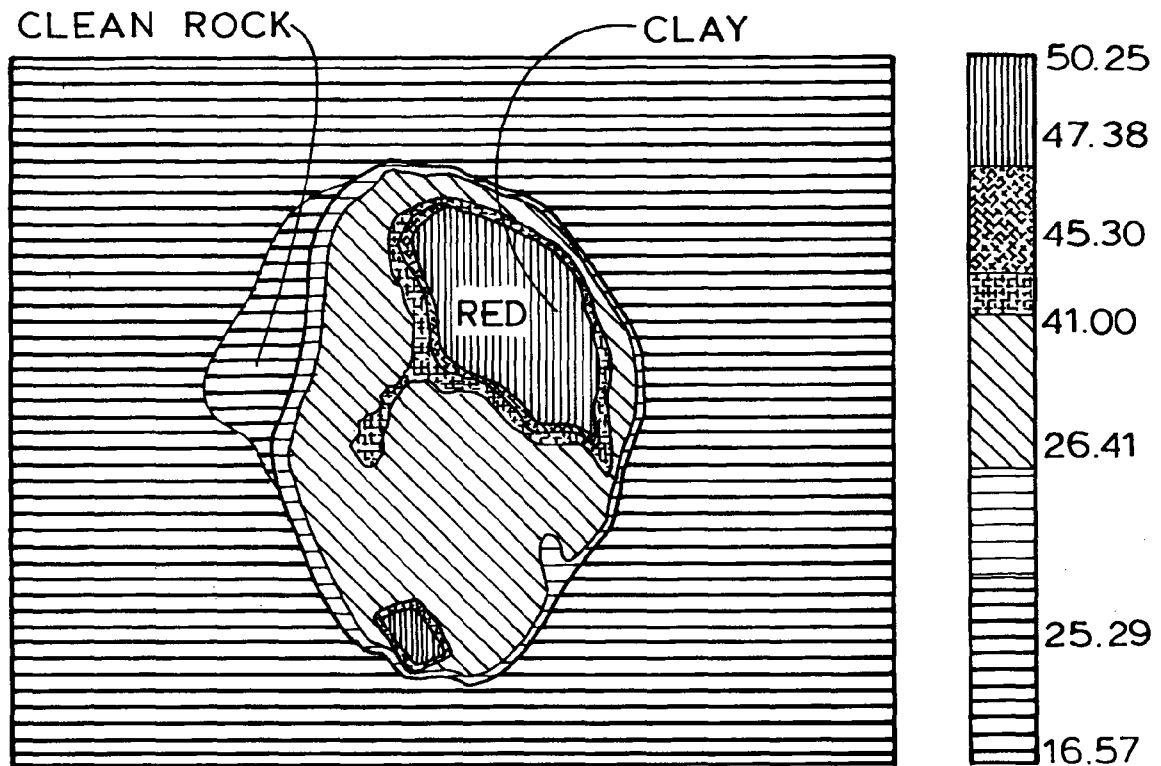


FIG. 4

Infra-red image of the rock particle during microwave heating. Red (high temperature) areas correspond to the rapidly heating clay patches on the surface of the rock.

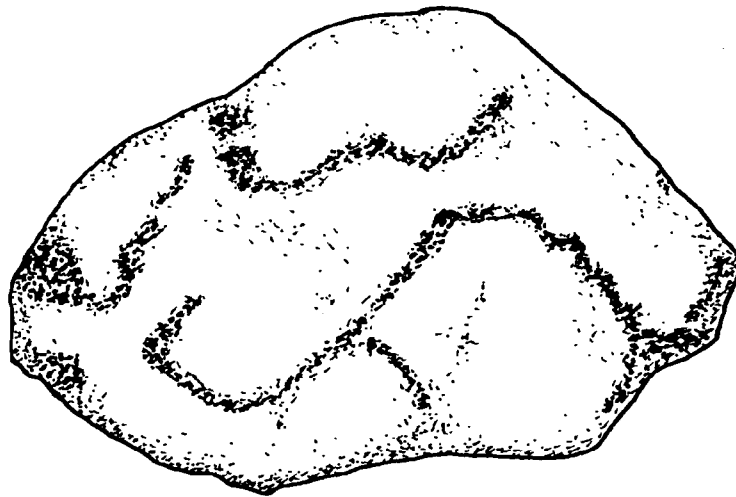
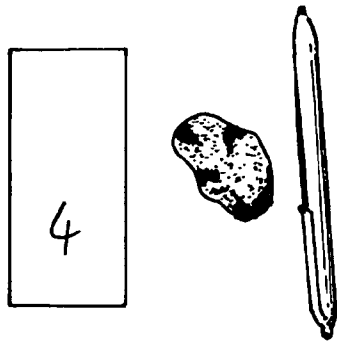
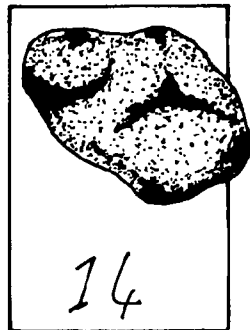
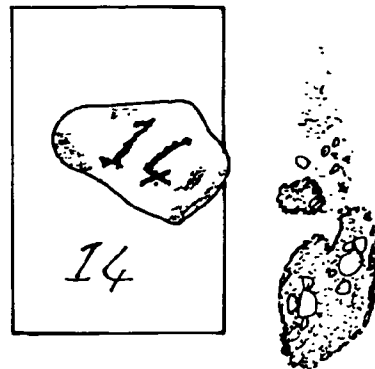


FIG. 5

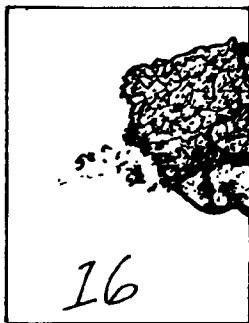
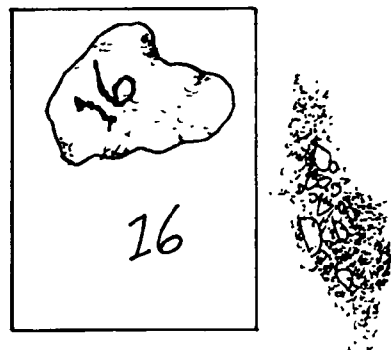
Rock particle after microwave heating, covered with cracked clay crust.

FIG. 6FIG. 6A

Rock fragmented covered with clay, before microwave heating (left) and after microwave heating and 10sec tumbling in plastic container.

FIG. 7FIG. 7A

Rock fragmented covered with clay, before microwave heating (left) and after microwave heating and 10sec tumbling in plastic container.

FIG. 8FIG. 8A

Rock fragmented covered with clay, before microwave heating (left) and after microwave heating and 10sec tumbling in plastic container.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2009/001160

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl. **B03B 1/00** (2006.01) **B03B 7/00** (2006.01) **F26B 3/347** (2006.01)
B03B 1/02 (2006.01) **C22B 1/00** (2006.01)
B03B 5/30 (2006.01) **C22B 4/00** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI and EPODOC: IPC marks B03B1/-, B03B5/-, B03B7/-, F26B3/-, C22B1/-, C22B4/- and keywords such as ore, mineral, bauxite, laterite, copper, dry, heat, warm, dehydrate, dewater, microwave, MW, Radio, RF, Radiation and similar keywords in Google patents and Espace

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	WO 2009/063482 A2 (ADITYA BIRLA SCIENCE AND TECHNOLOGY CO. LTD) 22 May 2009 See abstract, claim 1	
A	WO 2003/102250 A1 (TECHNOLOGICAL RESOURCES PTY LTD) 11 December 2003 Figure 1, abstract, claim 1	
A	WO 2006/037120 A2 (WAVE SEPARATION TECHNOLOGIES, LLC) 06 April 2006 See figure 1, claim 1, abstract	
A	WO 2006/034553 A1 (TECHNOLOGICAL RESOURCES PTY LTD) 06 April 2006 See figure 1, abstract, claim 1	



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Date of the actual completion of the international search
06 October 2009

Date of mailing of the international search report

14 OCT 2009

Name and mailing address of the ISA/AU
AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
E-mail address: pct@ipaaustralia.gov.au
Facsimile No. +61 2 6283 7999

Authorized officer
HERAMB M BAL
AUSTRALIAN PATENT OFFICE
(ISO 9001 Quality Certified Service)
Telephone No : +61 2 6283 7966

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2009/001160

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
WO	2009063482	NONE					
WO	03103250	AU	2002319845	EP	1523839	EP	1962472
		US	2005160152				
WO	2006037120	AU	2003216298	AU	2005289429	CA	2476784
		CN	1643170	EP	1488016	US	6923328
		US	7571814	US	2004258591	US	2005092657
		WO	03072835	ZA	200406723		
WO	2006034553	AU	2005289380	BR	PI0516852	CA	2582927
		CN	101068939	ES	2324326	US	2009013822
		ZA	200703472				
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.							
END OF ANNEX							